J. ENVIRONMENTAL SYSTEMS, Vol. 13(2), 1983-84

REGIONAL INTERINDUSTRY-ENVIRONMENTAL MULTIPLIERS BASED ON THE 1972 NATIONAL MODEL FORMAT

THOMAS R. HARRIS
Professor, Division of Agricultural and Resource Economics
University of Nevada, Reno

CHAUNCEY T. K. CHING
Professor and Chairman
Department of Agricultural and Resource Economics
University of Hawaii, Manoa

ABSTRACT

Public decision makers are faced with the dilemma of initiating regional economic growth while simultaneously conserving the region's natural resources and environment. In order to derive trade-offs between economic progress and environmental quality, an interindustry-environmental model is used. This study shows the derivation of an interindustry-environmental model based on the 1972 national input-output model format. Also the procedures to construct a regional interindustry model through the non-survey technique of location quotients are presented. From the regional interindustry model, an interindustry-environmental model of northcentral Nevada was developed to show the effects on regional water use and particulate emissions from the expansion of a particular commodity sector in the region. Interpretations of results from the interindustry-environmental model which are of interest to public policy makers are discussed.

Public policy decision makers have been faced with the trade-off problem of initiating regional economic growth while simultaneously conserving the region's natural resources and environment. The trade-offs are complicated in that the

doi: 10.2190/EGV6-Q2PU-J7HG-AQ1B
http://baywood.com

goal of regional economic growth can run counter to the objectives of resource and ecological preservation. It is possible to have a pristine environment, however the cost would be a low level of economic activity while the other alternative is to have a high level of economic activity with water resources seriously depleted or the environment polluted. Accordingly, policymakers are interested in quantitative measurement of trade-offs between regional economic growth and resource use and/or environmental quality.

One way of quantifying some of these relationships is through the use of Leontief input-output or interindustry model. Interindustry analysis depicts the interrelationships between different economic sectors of a regional economy and can be used for impact analysis. Bills and Barr [1], Bromley et al. [2], and Osborn et al. [3] have used interindustry models to estimate changes in regional economic activity, employment, and value added caused by increased sales or economic structural changes.

There is no reason, however, for interindustry analysis to focus solely upon economic multipliers (e.g., sales, income, and employment). Multipliers associated with resources and pollutants are also appropriate. Earlier studies by Leontief [4], Isard [5], Cumberland [6], and Laurent and Hite [7] have combined interindustry procedures with ecological data to estimate the effects on the region's resources and pollution emissions from increased sectoral output. In a later article by Harris and Ching [8], resource multipliers were generalized and expanded to include both economic and resource effects.

The problem facing many public policy makers using these interindustry procedures is the limited availability of regional input-output models and direct resource coefficients which are needed to generate economic-ecological trade-offs. As a partial solution to this availability problem this paper suggests an operational approach to estimate these trade-offs. Specifically, the use-make format of the latest national input-output model was utilized along with a procedure for specifying a regional input-output model that is relatively efficient (location quotient approach), and a procedure for simultaneously estimating the economic and environmental impact associated with a specific application to a region in northcentral Nevada.

Consistent with this objective, this paper is organized into four main parts. First, we discuss the 1972 national input-output model format. This is done because the format is different than earlier input-output models; and, we utilize some of the notation in developing subsequent multipliers. Second, we discuss a non-survey procedure for estimating a regional input-output model from a national model. The procedure used is the location quotient approach by Mustafa and Jones [9]. Third, we explicitly specify the economic-ecological multipliers based on the 1972 input-output format. Fourth, we apply these procedures to the Humboldt-Lander County area in northcentral Nevada.

THE 1972 INTERINDUSTRY MODEL FORMAT

In 1972, the procedure of developing the national input-output model changed. The current format of the national interindustry model closely follows the United Nations format. The first change was that industry classifications were based on Standard Industrial Codes of 1972 instead of 1967. The second change was the treatment of secondary products. Before 1972, industries were classified by their primary product, the product accounting for the largest percentage of the business' production. Secondary products were not considered, and their sales and production processes were incorporated into the primary and secondary products in its tables [10, 11].

The 1972 model developed two definitions that helped in accounting for both primary and secondary products. These definitions are input-output industries and input-output commodities. An input-output industry is a grouping of industries established and classified by the 1972 Standard Industrial Codes while an input-output commodity consists of characteristic products by the corresponding input-output industry. The input-output commodity is the primary product of an input-output industry plus the production of the same input-output commodity by other input-output industries.

Prior to 1972, the result of the national input-output model was presented in three tables: the Transactions Table, the Direct Requirements Table, and the Total Requirements Table. Because of the procedure to account for secondary products in the 1972 model, five tables are now used: The Use Table, the Make Table, the Commodity-by-Industry Direct Requirements Table, the Commodity-by-Commodity Total Requirements Table, and the Industry-by-Commodity Total Requirements Table.

The Use Table

The Use Table shows the dollar flows of goods and services throughout the regional economy. In the Use Table, the commodities appear as rows while the industries that produced these commodities as primary products appear along the column head. Therefore, going along the rows of the Use Table, commodity sales to industries and final demand users can be seen, and tracing down a selected column the purchase of commodities and value added by each industry are shown.

In mathematical notation, industry total gross output (G_j), that is; output of both primary and secondary products by an industry, are presented below as:

$$G_j = \sum_{i=1}^{m} U_{ij} + VA_j \qquad j = 1,2, \ldots, n \tag{1}$$

where:

- G_j is total output by industry j (primary and secondary products),
- U_{ij} is the dollar value of commodity inputs i, including imports of produced commodities, scrap, and imports of noncomparable commodities used by industry j,
- VA_j is the value added by industry j,
- m is the number of commodities including scrap and noncomparable imports, and
- n is the number of industries.

Scrap is defined as unplanned output by an industry which, for example, could be leftover rails in the railroad industry which may be sold to steel industries. Provisions to handle scrap will be discussed later. Imports have two classifications, comparable and noncomparable imports. Comparable imports are those imports of commodities which are comparable to domestically produced commodities. Comparable imports are entered as negative values so that each row total will be domestically produced commodities. Noncomparable imports are those imports which are not comparable to domestically produced commodities and are shown as a row value.

The summation of the row entires in the Use Table (Q_i) gives the total output of commodity i which includes both scrap and noncomparable imports.

$$Q_i = \sum_{j=1}^{n} U_{ij} + E_i \qquad i = 1, 2, \ldots, m \qquad (2)$$

where:

- Q_i is the total output of commodity i which includes scrap and noncomparable imports,
- U_{ij} is previously defined,
- E_i is final demand including exports less imports for commodity i,
- m is the number of commodities plus scrap and noncomparable imports, and
- n is the number of industries.

The Make Table

The Make Table is an industry-by-commodity table which is the reverse of the Use Table and describes the dollar value of primary and secondary products produced by each industry. Along the main diagonal of the Make Table is the primary product of the industry named at each row heading. The other row values off the main diagonal are the secondary products of the particular industry. The column entries of the Make Table show the amount of commodity produced by each industry sector.

In mathematical notation, the summation of row entries in the Make Table derives total industry i output (G_1), or:

$$G_i = \sum_{j=1}^{m} V_{ij} + H_i \qquad i = 1, 2, ..., n \qquad (3)$$

where:

G_i is the total output of industry i,
V_{ij} is the value of commodity j produced by industry i, with zero values for noncomparable imports and scrap entries, and
H_i is the dollar value of scrap produced by industry i.

Column entries for scrap and noncomparable entries have zeroes which reflect the fact that there are no national production functions for imports or scrap. By going down the column of the Make Table, each V_{ij} is the value of commodity j produced by each industry i so that the columnar summation yields total commodity j output (Q_j).

The Market Share Table

From the Make Table, a Market Share Table can be developed which shows the proportional share of commodity j produced by industry i, or shown as:

$$d_{ij} = V_{ij}/Q_j \qquad i = 1, 2, ..., n \qquad (4)$$
$$j = 1, 2, ..., m \qquad (5)$$

where:

d_{ij} is the percentage of commodity j produced by industry i.

In the Market Share Matrix, there are values for the first (m-2) columns, however the last two columns representing the scrap and noncomparable imports sector are zero. Also, the relationship of the Make Table and Market Share Table can be shown in Equation 5 as:

$$V = D\,\hat{Q}$$

where:

V is the (nxm) Make Table with zeroes in columns for noncomparable imports and scrap sectors,
D is the (nxm) Market Share Table of d_{ij}'s,
$\hat{Q}$ is the (mxm) matrix of zeroes except along the main diagonal which has total commodity j outputs.

The Commodity-by-Industry Direct Requirements Table

The Commodity-by-Industry Direct Requirements Table is similar to the Direct Requirements Table used by input-output models developed previous to 1972. Each element in the Use Table (U_{ij}) is divided by its corresponding column sum (G_j) which derives the value of commodity i necessary to produce a dollar's worth of industry j output, or stated as:

$$b_{ij} = U_{ij}/G_j \qquad i = 1, 2, ..., m \qquad (6)$$
$$j = 1, 2, ..., n \qquad (7)$$

where:

b_{ij} is the proportional amount of commodity i necessary to produce a dollar's worth of industry j output.

In relating the Direct Requirements Table to the Use Table, the following matrix equation is derived as:

$$U = B\,\hat{G}$$

where:

U is the (mxn) portion of the Use Table,
$\underset{\sim}{B}$ is the (mxn) Direct Requirements Table, and
$\hat{G}$ is the (nxn) matrix of zeroes except for the main diagonal which has total industry j output.

Tracing down the column entries of the Direct Requirements Matrix derives a production recipe for each commodity required by a particular industrial sector in its production process.

The Scrap Vector

As mentioned earlier, scrap is unplanned output of an industry. If scrap is produced, it is assumed to be produced in a fixed proportion to the industry's output. Scrap is treated, however, in such a way as to prevent its requirement as an input from generating output in industries from which it is produced. The scrap coefficients are defined as:

$$P_i = h_i/G_i \qquad i = 1, 2, ..., n \qquad (8)$$

where:

P_i is the proportion of scrap to total industry i output, and
h_i is the dollar value of scrap produced by industry i as shown in the Make Table.

The matrix relationship of scrap production to industry output can be shown as:

$$H = \hat{P}\, G \qquad (9)$$

where:

H is a (nxl) vector of scrap production,
P is a (nxn) matrix of zeroes except the main diagonal which contains the individual P_i values or the fixed percentage of the industry's output that is scrap, and
G is a (nxl) vector of total industry output.

The Total Requirements Table

In this section the development of the Commodity-by-Commodity Table and the Industry-by-Commodity Table will be discussed. The development of the Commodity-by-Commodity Table will require estimating the M matrix. The M matrix will describe the relationship of total final demand to total commodity output, or stated as:

$$Q = M\, E \qquad (10)$$

Equation 2 can be stated in matrix form as:

$$Q = Ui + E \qquad (11)$$

where:

Q is a (mxl) vector of total commodity outputs including scrap and noncomparable impacts,
U is a (mxn) intermediate portion of the Use Table,
i is a (nxl) summation vector of l's, and
E is a (mxl) vector of final demands including exports less imports.

Using the Commodity-by-Industry Direct Requirements Matrix (Equation 7), the (nxl) G vector of total industry outputs, and Equation 11 yields:

$$Q = B\, G + E \qquad (12)$$

Using the Market Share Matrix derived in Equation 5, the (mxl) vector of total commodity outputs and Equation 3 written in matrix form yields:

$$G - H = D\, \hat{Q} \qquad (13)$$

Substituting Equation 9 into Equation 13 and solving for G yields:

$$G - \hat{P}\, G = D\, \hat{Q}$$
$$(I-\hat{P})\, G = D\, \hat{Q}$$
$$G = (I-\hat{P})^{-1}\, D\, \hat{Q} \qquad (14)$$

If let $W = (I-\hat{P})^{-1}$ D yields:

$$G = W \hat{Q} \quad (15)$$

The W matrix changes the commodity outputs to industry outputs by inflating commodity output by scrap. The premultiplication of the Market Share Matrix D by $(I-P)^{-1}$ weights the industry output requirements to produce a dollar's worth commodity by the share of total commodity output produced by each industry.

Substituting 15 into 12 and solving for Q derives:

$$Q = B W G + E$$
$$(I-BW) Q = E$$
$$Q = (I-BW)^{-1} E \quad (16)$$

Where $(I-BW)^{-1}$ is the M matrix relating commodity output to total final demand. The column sums are commodity output multipliers which estimate the total requirements of all commodities necessary to produce one dollar of total final demand for commodity listed at the column head.

The second Total Requirements Table is the Industry-by-Commodity Total Requirements Table which is represented by matrix N. The N matrix describes the relationship between total industry output (G) and total final demand as:

$$G = N E \quad (17)$$

Because W translates commodity output to industry output, matrix N is solved directly as:

$$N = W (I-BW)^{-1} \quad (18)$$

$$G = W (I-BW)^{-1} E \quad (19)$$

where $W(I-BW)^{-1}$ is the matrix N which related total industry output to final demand. The column sums are called industry output multipliers which relates to the total requirements of all industries necessary to supply one dollar of total final demand for the commodity named at the head of the column. These two total requirements tables estimate the overall impact on commodity output and industry production from changes in total final demand.

DERIVATION OF REGIONAL MODELS USING THE LOCATION QUOTIENT METHOD AND THE 1972 U.S. MODEL FORMAT

There are many approaches in deriving regional interindustry models either by survey or nonsurvey techniques. The survey technique develops a regional interindustry model from interviews of selected businesses within the regional boundaries in order to derive transaction data. The survey method is both time consuming and costly. Given time and budget restrictions, methodologies have been developed which use nonsurvey methodologies to derive regional input-output models. Techniques such as the location quotient approach and pool techniques have been used. Schaffer and Chu [12] and Czamanski and Malizia [13] have studied and compared many nonsurvey techniques. Results of their studies have shown that when compared to input-output models derived through survey techniques, the location quotient procedure has proved the best of the nonsurvey techniques. For this study, the location quotient algorithm used was developed by Mustafa and Jones [9]. However, this location quotient algorithm was changed slightly to incorporate the 1972 interindustry format.

Location Quotient Procedure

The location quotient procedure is based on comparing the relative importance of an industry in a region to its relative importance in the nation. The location quotient is defined as:

$$LQ_i = (Z_i/Z) \div (X_i/X) \tag{20}$$

where:

Z_i is the regional output of industry i for the base year,
X_i is the national output of industry i for the base year,
Z is total regional output for the base year, and
X is total national output for the base year.

Location quotients compare the percentage share of a particular sector's output of a region with the percentage share of that sector's output of the nation. If the region's share is equal to the nation's share then the location quotient is one, and the industry in the region is assumed to be self-sufficient. If the industry of the region produces more than its proportional share, the location quotient is greater than 1. The industry of the region is assumed to export the surplus production. However, if an industry of a region produces less than its proportional share, the location quotient is less than 1 and the region is assumed to import the deficit production.

If the location quotient is 1 or more, all national technical coefficients for that sector's row may be used directly to represent regional direct requirements coefficients. However, if the location quotient is less than 1, the national coefficients of the sector's row are reduced proportionately to account for the region's deficit production. The location quotient procedure will be used to derive the Regional Use Table in this paper.

The Regional Make Table

The initial step in producing regional interindustry tables from the 1972 U.S. formatted input-output model is to develop a regional make table. The regional Make Table will follow the assumptions of Di Pietre et al., [11] in that regional industries are assumed to produce the same primary and secondary products as the national industries and that each regional industry is proportionately identical to its corresponding national industry in the production of primary and secondary products. From these assumptions, the regional elements of the Make Table are derived as:

$$v_{ij} = \frac{V_{ij}}{G_i} g_i \qquad (21)$$

where:

v_{ij} is the regional Make Table elements,
V_{ij} is the national Make Table elements
G_i is the national total industry i output, and
g_i is the regional total industry i output.

Regional total commodity outputs necessary for estimation of the regional Use Table can be derived from the regional Make Table as:

$$q_j = \sum_{i=1}^{n} v_{ij} \qquad j = 1, a, \ldots, m \qquad (22)$$

where:

q_j is total regional commodity j output,
m is the number of commodities, and
n is the number of industries.

The Regional Use Table

After total commodity outputs are derived, the regional Use Table can be estimated. Regional and national commodity outputs are used to derive location quotients because commodity outputs do not include scrap and secondary products like industry output totals. The procedures of the location quotient algorithm follow essentially the same as the study by Mustafa and Jones [9] except the Use Table is balanced so that row totals equal regional commodity output values and column totals equal regional industry output totals. A unique feature of the regional Use Table is that an imports row is necessary at the regional level because the region imports from both national and international suppliers while the national economy only imports from international sources.

ECONOMIC-ENVIRONMENTAL MULTIPLIERS

Ching described a procedure for developing a matrix of water multipliers using interindustry models prior to the 1972 model [14]. Also, in a reference study by Harris and Pierce [15], water multipliers as they relate to regional employment and incomes were estimated. The procedures described in the previous two studies were expanded to include pollutant information so that pollutant multipliers as well as resource multipliers could be estimated.

For the 1972 interindustry format, the general procedure as shown by Ching is followed with the Interindustry-by-Commodity Matrix depicting the economic sector interrelationships [14]. In order to derive environmental multipliers, it is first necessary to estimate direct environmental requirements. Direct environmental requirements show the quantity of a particular environmental factor used per unit of industrial sector output, or:

$$r_{ij} = L_{ij}/G_i \qquad i = 1, 2, ..., n \quad j = 1, 2, ..., k \tag{23}$$

where:

r_{ij} is the amount of environmental factor j used per unit of industry i output (if the jth environmental factor is a resource the coefficient r_{ij} is positive, however if the jth environmental factor is a pollutant the r_{ij} is negative).

L_{ij} is the total quantity of environmental factor j used in production by industry i, and

G_i is total industry output by sector i.

Using the direct environmental coefficients and the Industry-by-Commodity Total Requirements Matrix, total regional resource use of pollution emissions created by changes in commodity final demand sales can be estimated. These total environmental impacts are shown in matrix T as:

$$T = N' R \tag{24}$$

where:

T is an (nxk) matrix of direct and indirect environmental use for n sectors and k environmental factors; elements of T are t_{ij}. If the jth environmental factor is a resource the coefficient will be positive. If the jth environmental factor is a pollutant the coefficient will be negative. For the jth environmental factor, t_{ij} is referred to as the "jth environmental factor-final demand coefficient."

R is (nxk) matrix of direct environmental coefficients for n sectors and k environmental factors; elements of R are r_{ij},

N is (nxm) matrix of Industry-by-Commodity Total Requirements.

Employment and income multipliers can be derived using the same procedures as shown in Equations 23 and 24. A detailed explanation of deriving employment and income multipliers is presented by Harris and Ching [8].

REGIONAL ENVIRONMENTAL MULTIPLIERS FOR HUMBOLDT AND LANDER COUNTIES

Derivation of a regional interindustry model for the northern Nevada counties of Humboldt and Lander using the 1972 U.S. input-output model was made. Also regional water, particulate emissions, employment and income multipliers were estimated.

Following procedures outlined in Equation 21, a Make Table for Humboldt and Lander Counties was derived. The national 86-sector model was collapsed to a more usable 9-sector model. After deriving the Make Table, commodity output values were derived. The estimated regional commodity output values were used along with the location quotient algorithm developed by Mustafa and Jones [9] to derive the Use Table for Humboldt and Lander Counties.

From the Humboldt and Lander County Make and Use Tables, the Industry-by-Commodity Total Requirements Table was calculated. With the Industry-by-Commodity Total Requirements Table along with estimates of direct environmental factor use, a matrix of regional environmental factor use from changes in commodity sales by final demand were estimated. Prior to the 1972 model format, a change in a specific industry's sales to final demand would estimate the effects on regional environmental factors. However, with the 1972 model format, the effects on regional environmental factors from increased commodity final demand sales are derived. That is, before the 1972 model format the effects on the regional economy and environment from increased final demand sales of secondary products by an industry were not included. Only the economic sector's primary product effects were estimated. With the 1972 interindustry model format, the environmental interrelationships of both primary and secondary products of an economic sector were derived.

For this paper, two environmental factors were investigated. The resource factor was water and the pollution factor was particulates emitted into the air. Water use for each industrial sector was derived from a study by Uwakonye [16], while the pollution data as the tons of particulates emitted by industrial sector was derived from data supplied by the Nevada Environmental Protection Agency [17]. Table 1 shows the effects on regional water use, particulate emissions, income and employment from changes in commodity sales to final demand.

From Table 1 and procedures outlined by Harris and Ching [8] water-self, water-income, and water-employment multipliers are shown in Table 2 while particulate-self, particulate-income, and particulate-employment multipliers are shown in Table 3. The direct water multiplier for the Agriculture Industrial Sector is 9.5266 which means for each $1,000 increase in output by the

Table 1. Direct Water Coefficients, Direct Particulate Coefficients, Water-Final Demand Multipliers, Income Multipliers and Employment Multipliers Per $1,000 of Output By Sector In The Humboldt and Lander Economy

Sector	*Direct Water Coefficient (acre-foot)*	*Direct Particulate Coefficient (tons)*	*Water Final Demand Multiplier (acre-foot)*	*Particulate-Final Demand Multiplier (tons)*	*Income-Final Demand Multiplier (dollars)*	*Employment-Final Demand Multiplier (labor)*
1. Agriculture	9.5266	-0.6993	13.9253	-1.0545	0.6860	0.0356
2. Mining	0.1587	-2.2576	0.1857	-2.4157	0.7545	0.0279
3. Construction	0.0006	-0.9260	0.0569	-0.9645	0.6109	0.0348
4. Manufacturing: Non-Durable	0.0107	-0.0118	4.9668	-1.4424	0.6973	0.0347
5. Manufacturing: Durable	0.1470	-0.0113	0.5090	-0.1734	0.5647	0.0301
6. Transportation, Communication and Public Utilities	0.0024	-0.1515	0.0523	-0.3057	0.8344	0.0409
7. Wholesale and Retail Trade	0.0013	-0.0	0.0381	-0.0224	0.8969	0.0831
8. Finance, Insurance and Real Estate	0.0001	-0.0	0.0419	-0.0313	0.8314	0.0213
9. Services	0.0442	-0.0	0.1766	-0.0500	0.7573	0.0644

Table 2. Water-Self Multipliers, Water-Income Multipliers, and Water-Employment Multipliers by Sector in Humboldt and Lander Economy

Sector	*Water-Self Multiplier*	*Water-Income Multiplier*	*Water-Employment Multiplier*
	(acre-feet)		
1. Agriculture	1.46	20.29	391.16
2. Mining	1.17	0.25	6.66
3. Construction	94.81	0.09	1.64
4. Manufacturing: Nondurable	464.19	7.12	143.14
5. Manufacturing: Durable	3.46	0.90	16.91
6. Transportation, Communication, and Public Utilities	21.80	0.06	1.28
7. Wholesale and Retail Trade	29.33	0.04	0.46
8. Finance, Insurance, and Real Estate	419.02	0.05	1.97
9. Services	4.00	0.23	2.74

Agriculture Industrial Sector, it requires 9.5266 acre-feet. The direct particulate coefficient is interpreted that for each $1,000 increase in output by the Mining Industrial Sector approximately 2.26 tons of particulates are emitted. The final demand-water multiplier for the Agriculture Industrial Sector is 13.93 acre-feet. Thus, when sales to final demand by the Agriculture Commodity Sector increases by $1,000, regional water use increases by 13.93 acre-feet. Also from Table 1, the final demand particulate multiplier for the Mining Industrial Sector is 2.42. Therefore, when sales to final demand by the Mining Commodity Sector increases by $1,000, regional particulate emissions increased by 2.42 tons. Final demand income and final demand employment multipliers in Table 1 show the increase in regional income and employment if a commodity sector increased sales to final demand by $1,000.

Sectoral water-self multipliers are shown in Table 2. The water-self multiplier gives an indication of the total quantity of water required from the region when the direct water using industrial sector, increases water use by one acre-foot. From Table 2, the Finance, Insurance, and Real Estate Industrial Sector has a water-self multiplier of 419.02. This means, when the Finance, Insurance and Real Estate Industrial Sector increases water use by one acre-foot in its production process, it requires a total regional water use of approximately 419.02 acre-feet. As seen from Table 1, the Finance, Insurance and Real Estate Industrial Sector is

Table 3. Particulate-Self Multiplier, Particulate-Income Multiplier, and Particulate-Employment Multiplier by Sector in Humboldt and Lander Economy

Sector	*Particulate-Self Multiplier*	*Particulate-Income Multiplier*	*Particulate-Employment Multiplier*
	(tons)		
1. Agriculture	-1.51	-1.54	-29.62
2. Mining	-1.07	-3.20	-86.58
3. Construction	-1.04	-1.58	-27.72
4. Manufacturing: Nondurable	-122.23	-2.07	-41.57
5. Manufacturing: Durable	-15.35	-0.31	-5.76
6. Transportation, Communication, and Public Utilities	-2.02	-0.37	-7.47
7. Wholesale and Retail Trade	[a]	-0.02	-0.27
8. Finance, Insurance and Real Estate	[a]	-0.04	-1.47
9. Services	[a]	-0.07	-0.78

[a] *Particulate-self multipliers are derived only for sectors which directly emitted particulates in their production processes.*

a low direct water user. However, because of its interrelationships with high direct water users, the water-self multiplier for the Fire, Insurance and Real Estate Industrial Sector is large. Also the Fire, Insurance, and Real Estate Industrial Sector has a large water-self multiplier because of its low direct water use coefficient. That is, for the Fire, Insurance, and Real Estate Industrial Sector to increase water use by one acre-foot, the industrial sector would have to experience approximately a ten million dollar increase in production.

Water multipliers are useful in assessing water use requirements to changes in output by various industrial sectors in Humboldt and Lander economy. However, these multipliers alone do not adequately evaluate the trade-offs between household income and water use. Table 2 shows the effects on regional water use from a one-unit increase in sectoral household income by a given sector. For example, water use increases by approximately 0.05 acre-feet from a $1.00 increase in household income by the Fire, Insurance and Real Estate Industrial Sector.

Regional water requirements from a one-unit increase in employment by a given economic sector is shown in Table 2. For example, total regional water use increased by 1.97 acre-feet per one-unit increase in employment by the Fire, Insurance and Real Estate Industrial Sector. Water-employment multipliers like water-income multipliers derive approximations of trade-offs between sectoral employment growth and water use in Humboldt-Lander study area.

However, with regional economic growth not only are resources depleted, pollution also may increase. Sectoral particulate-self multipliers are shown in Table 3. The particulate-self multiplier gives an indication of total particulates emitted into the regional environment when the direct particulate emitting sector increases emissions by one ton of particulate in its production process. From Table 3, the Manufacturing Non-Durable Industrial Sector has a particulate-self multiplier of 122.23. This means, when the Manufacturing Non-Durable Industrial Sector increases particulate emissions by one ton in its production process, total particulate emissions in the regional economy because of interactions between the economic sectors increases by 122.23 tons of particulates. As with the water-self multipliers, an industrial sector like the Manufacturing Non-Durable Industrial Sector is a low direct particulate emitting sector. However, because of interdependencies between other regional industrial sectors, the Manufacturing Non-Durable Industrial Sector has a large particulate-self multiplier. Also, for the Manufacturing Non-Durable Industrial Sector to increase particulate emissions by one ton, production by this sector would have to increase by approximately $93,500 which contributes to the size of the particulate-self multiplier.

Particulate multipliers are useful in assessing pollution emission into the environment. However, to evaluate trade-offs between regional household income and/or regional employment increases to particulate emissions in the region, particulate-income and particulate-employment multipliers as shown in Table 3 are used. For example, particulate emissions increase by approximately 2.07 tons from a $1.00 increase in household income by the Manufacturing Non-Durable Industrial Sector.

Regional particulate emissions from a one-unit increase in employment by a given interindustry industrial sector are shown in Table 3. For example, total regional particulate emissions increased by 41.57 tons per one-unit increase in employment by the Manufacturing Non-Durable Industry Sector. Particulate-employment multipliers like particulate-income multipliers derive approximate trade-offs between industry sectoral employment growth and particulate emissions in the Humboldt-Lander study area.

Also from Tables 1 and 3, the existence of ecological linkages for sectors which do not directly emit particulates into the air in their production processes are shown. This ecological linkage occurs from the economic interdependencies among regional sectors. An industrial sector like the Service Industrial Sector has no direct effect on the environment from particulate emission. However, the

Service Industrial Sector must purchase inputs from other regional industry sectors which do directly emit particulates into the air. Therefore, the Service Industrial Sector through its purchases causes increased production by the supplying sectors which may indirectly cause increased particulate emissions to occur.

For example, when the Service Industrial Sector increases employment by one employee, regional particulate emissions will increase by 0.78 tons (Table 3). Therefore, indirectly all economic sectors have environmental linkages and affect the region's environment when they increase output.

ENVIRONMENTAL MULTIPLIERS IN REGIONAL PLANNING

The interindustry-environmental model can provide decision makers and planners with information concerning the trade-offs between income or economic expansion and the effects on regional resource supplies and environmental quality. The results of the model show that income or employment growth cannot occur in the region without some loss in regional water resource and/or environmental quality. Industry sectors which have large income or employment multipliers also have a high level of economic interdependence with other regional industry sectors. Because of this interdependency with other industry sectors, the industry sector will require substantial quantities of the region's resources and may substantially injure regional environmental quality.

Table 4 contains the estimated change in regional income, employment, water use, and particulate emissions due to a \$100,000 change in final demand for each commodity sector. The Mining Industrial Sector, for example, has a water-self multiplier of 1.17 and a particulate-self multiplier of 1.07. Although these multipliers are small, the total impact on water use and particulate emissions due to a \$100,000 change in final demand for the Mining Commodity Sector yields a total change in water use of approximately 18.6 acre-feet and total change in particulate emissions of 241.6 tons. On the other hand, the Wholesale and Retail Industrial Sector has a relatively large water-self and particulate-self multiplier. However a \$100,000 change in sales to final demand by this sector yields only a total change in water use of approximately 3.8 acre-feet and change in particulate emissions of 2.2 tons. Thus, one cannot simply utilize the magnitudes of the water-self and particulate-self multipliers but must remember that the impact is in terms of changes in final demand for the product of the commodity sector in question. If water and particulate multipliers are interpreted correctly, they have a definite place in evaluating the impact of growth or decline in a particular economy. They are no less important than the typical measures of income and employment.

Water and particulate multipliers, when correctly used, provide a way of assessing the impacts of alternative economic development on regional water use

Table 4. Estimated Change in Regional Income, Employment, Water Use, and Particulate Emissions Due to $100,000 Change in Final Demand in Each Commodity Sector of the Humboldt and Lander Economy

Sector	*Income ($1,000)*	*Employment (FTE's)*	*Water (acre-feet)*	*Particulates (tons)*
1. Agriculture	68.6	3.6	1392.5	-105.5
2. Mining	75.5	2.8	18.6	-241.6
3. Construction	61.1	3.5	5.7	-96.5
4. Manufacturing Non-Durable	69.7	3.5	496.7	-144.2
5. Manufacturing Durable	56.5	3.0	50.9	-17.3
6. Transportation, Communication, and Public Utilities	83.4	4.1	5.2	-30.6
7. Wholesale and Retail Trade	89.7	8.3	3.8	-2.2
8. Finance, Insurance and Real Estate	83.1	2.1	4.2	-3.1
9. Services	75.7	6.4	17.7	-5.0

and particulate emissions. By embodying the operation of a regional economy (input/output model) and the use of water by regional economic sectors (water coefficients) or particulate emissions by regional sectors (direct particulate coefficients), the water and particulate multipliers form a crucial link between an economic development strategy and a scarce natural resource and/or quality of regional environment. Thus, water and particulate multiplier analysis is a convenient way of relating the multiplier objectives of regional water use, particulate emissions, and a particular economic development alternative.

The availability of water and quality of the environment is only one set of the many objectives and constraints to be considered by regional decision makers. Besides the economic considerations, there are political, social, legal, and other aspects that enter into regional decision making. While the following discussion centers on the quantity of water resource and quality of environment, other inputs will enter the decision making process.

Multiplier analysis allows comparisons of the change in a limited resource such as water or the emission of pollution-like particulates to regional development alternatives. Given adequate water availability and/or environmental quality, a wide range of alternative actions may be available to the environmental planner or decision maker. If the change in water use of particulate emissions due to an economic development action does not exceed the perennial pumping yield of the available water resource or threshold level for particulate emissions, the planner is free to select the most appropriate alternatives. However, if total water use and particulate emissions resulting from expansion in a particular economic sector exceeds resource availability and/or particulate emissions standards, that alternative action should be eliminated from consideration on the basis of resource availability and/or environmental quality.

Finally, it should be noted that this approach assumes the level of physical resource and environmental quality for a given regional economy to be known with certainty. This assumption is never completely satisfied because resource and pollution levels are always associated with probability distributions. However accompanying this analysis with the knowledge of most likely and least likely estimates of water availability and environmental quality will provide sufficient information to the decision maker. Also, the model is performed in a static time period. A dynamic interindustry-environmental model would incorporate the dynamics of economic growth, resource use, and pollution emissions and abatement which could be used by regional decision makers to develop proper time path expansions for their economies.

CONCLUSIONS

The primary objective of this paper was to develop an operational approach for estimating trade-offs between regional resource use and/or environmental quality to regional economic development. A specific objective was to show how the 1972 national interindustry model format can be used to develop a regional input-output model and formulate the interactions between economic sectors and environmental factors. The major advantage of using the 1972 interindustry model format is the handling of secondary commodity products produced by an economic sector.

Prior to the 1972 national model format, secondary products of an industrial sector were either included in the sales and inputs of the primary products or eliminated altogether. However, with the 1972 model format, secondary products are handled separately from primary products so that their effects on regional economic activity, resource use, and pollution emissions will be included in impact analysis.

Further, this paper shows the development of a regional interindustry-environmental model for two northern Nevada counties based on the 1972 national model format. A discussion of water and particulate multipliers was presented as well as their use for regional economic development. The basic point made was that physical multipliers (water and/or particulate multipliers) are just as important for economic development considerations as the traditional economic multipliers (output, income, and employment multipliers).

REFERENCES

1. N. L. Bills and A. L. Barr, *An Input-Output Analysis of the Upper South Branch Valley of West Virginia*, West Virginia University Agricultural Experiment Station Bulletin 568T, 1968.
2. D. W. Bromley, G. E. Blanche, and H. H. Stoevner, *Effects of Selected Changes in Federal Land Use on a Rural Economy*, Oregon State University Agricultural Experiment Station Bulletin 604, 1968.
3. J. E. Osborn, H. W. Grubb, and T. R. Harris, *An Input-Output Model Analysis of Texas High Plains Labor Employment Potentials to 1980,* Office of the Governor, Office of Information Services, Technical Report T-1-116, 1973.
4. W. Leontief, Environmental Repercussions and the Economic Structure: An Input-Output Approach, *The Review of Economics and Statistics, 52*, pp. 262-271, 1970.
5. W. Isard, C. L. Choguill, J. Kissin, R. H. Seyfarth, and R. Tatlock, *Ecologic-Economic Analysis for Regional Development*, The Free Press, New York, 1972.
6. J. H. Cumberland and R. J. Korbach, A Regional Interindustry Environmental Model, *Regional Science Association Papers, XVI*, pp. 61-75, 1966.
7. J. C. Hite and E. A. Laurent, Empirical Study of Economic-Ecological Linkages in a Coastal Area, *Water Resources Research, VII*, pp. 1070-1078, 1971.
8. T. R. Harris and C. T. K. Ching, Economic Resource Multipliers for Regional Impact Analysis, *Water Resources Bulletin, 19:*2, pp. 205-210, 1983.
9. G. Mustafa and L. Jones, *Regional Input-Output Models Using Location Quotients*, Department of Agricultural Economics, Texas A & M University, Agricultural Economics Program and Model Documentation, 71-4, 1971.
10. P. M. Ritz, *Definitions and Conventions of the 1972 Input-Output Study*, Bureau of Economic Analysis, Department of Commerce, Washington, D.C., 1980.
11. D. DiPietre, R. Walker, and D. Martella, Developing Regional Input-Output Models from the U.N. Format Adopted by the U.S. in the New 1972 Input-Output Model, *Southern Journal of Agricultural Economics, 12:*1, pp. 143-149, 1980.
12. W. Schaffer and K. Chu, Non-Survey Techniques for Constructing Regional Interindustry Models, *Papers of the Regional Science Association, 23*, pp. 83-101, 1969.

13. S. Czamanski and E. Malizia, Applicability and Limitations in the Use of National Input-Output Tables for Regional Studies, *Papers of the Regional Science Association, 23*, pp. 65-77, 1969.
14. C. T. K. Ching, Water Multipliers – Regional Impact Analysis, *Water Resources Bulletin, 17:*3, pp. 454-457, 1981.
15. T. R. Harris and B. S. Pierce, *Derivation and Applications of an Interindustry Resource Model for Humboldt and Lander Counties*, Department of Agricultural Economics, University of Nevada, Reno, Mimeo Series M.S.-147, 1981.
16. M. Uwaknoye, Estimation of Water Multipliers for the Humboldt and Lander Counties, Department of Agricultural Economics, University of Nevada, Reno, Professional Paper, 1979.
17. Division of Environmental Protection, unpublished data, State of Nevada, Carson City, Nevada, 1982.

Direct reprint requests to:

Thomas R. Harris
Division of Agriculture and
Resource Economics
University of Nevada, Reno
Reno, NV 89507