Regional Input-Output Analysis of An Environmental Regulation*

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I. Introduction

Coal is an important energy source of domestic supply in the United States for its substitutability for oil in electricity generation and the abundance of domestic coal reserves[1]. Coal has its problems as an energy source, however. For example, coal emits sulfur impurities polluting the atmosphere when it is used in energy applications. This sulfur emission is of great environmental concern of the public. Recent federal and state environmental legislation enforces the sulfur emission standard, and the resulting sulfur regulation stagnates coal mining industries by dampening the demand for coal. The regulation, in turn, surely has impacts especially on regional economies of coal mining areas.

Coal mining areas in the United States represent relatively depressed regions with lagged rates of growth. Concern for the economic development of such regions demands information on economic impacts of the sulfur emission control on coal mining and related industries of the regional economy. The input-output (I-O) analytical system serves as an extensive response to this

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1 The public interest of the United States on coal as an important energy source is explained, in part, by the growing opposition to nuclear power.

need. The construction cost of an I-O model by direct-survey methods is enormous in both temporal and monetary terms. The main objective of this paper is to develop an inexpensive nonsurvey I-O model for the coal mining region, and through the model to estimate economic impacts of the sulfur emission control.

This paper uses the 1978 data from coal producing counties in the state of Ohio. Section II defines the study region. Section III describes the construction procedures of a nonsurvey I-O model for the study region. Section IV analyzes empirical results of the economic impact analysis of the sulfur emission control. Section V presents conclusions and implications.

II. The Study Region

The state of Ohio is rich in coal. According to *the State of Ohio Division of Mines Report,* twenty-seven out of the state's eighty-eight counties, covering the east and southeast portion of the state, are currently producing coal (Figure 1). In 1977 about 47 milion short tons of coal were mined in this Ohio coal field (ODIR, 1978). With a decline, the coal production in million short tons was about 40 in 1978 (ODIR, 1979). This decline is, in part, due to the enforced sulfur emission control.

The major use of coal mined in Ohio is for the production of electricity (ACCC, 1978). Ohio coal has a high sulfur content. The majority of coal contains more than 3.5% sulfur which is far greater than the national average of 2.2% (Schlottmann, 1977). Recently, the enforced sulfur emission standard was imposed by the Clean Air Act on utilities in Ohio. According to Schweers, *et al.* (1979), an annual decline in the demand for Ohio coal of 3.1 million tons is expected due to this enforcement of the sulfur emission standard[2]. As a result of this decline, a total number of 2,050 Ohio jobs (910 jobs in the coal mining industry and 1,140 jobs in other related industries) are expected to be lost (Schweers, *et al.,* 1979; TBS, 1979). This surely portends further economic changes in Ohio coal producing counties.

The area of coal producing counties in Ohio is generally

2 See also TBS (1979).

Figure 1.

OHIO COAL PRODUCING COUNTIES AND THE STUDY REGION[1]

1. The figure represents each county's total coal production in 1,000 short tons in 1978. The state total as the sum of these figures is about 40 million. The area surrounded by a thick line is the study region. About 33 million short tons of coal were produced in this study region in 1978.

characterized by low per capita income and high unemployment. The per capita income in the area was about $6,167 in 1978 which is far less than per capita income of $7,826 in Ohio and $7,846 in the United States, (USDCa, 1981; USDCb, 1981). The unemployment outlook for the area is also bleaker than in other parts of Ohio and the United States. The rate of unemployment in the area was about 6.3% in 1978, while the state and national unemployment rates were about 5.4% and 6.0% respectively (OBESc, 1979).

The study region is confined to fifteen out of the twenty-seven coal producing counties in Ohio: Belmont, Carroll, Columbiana, Coshocton, Guernsey, Harrison, Holmes, Jefferson, Monroe, Morgan, Muskingum, Noble, Perry, Stark, and Tuscarawas (Figure 1). These counties are selected for three reasons. First, these fifteen counties represent the major coal producing region in Ohio. This fifteen county region produced 33 million short tons of coal in 1978 accounting for about 82% of the Ohio total (Figure 1).

Second, the fifteen county region composes the core of economic problems in coal mining areas. High unemployment and low income are the two major economic problems of this region, and the enforced sulfur emission control is expected to have significant effects on coal mining and related industries. Third, the fifteen counties form a contiguous region. For a small regional I-O analysis, it is better to form a contiguous region in the sense that it minimizes economic interference from outside the region (Richardson, 1972)

III. The Regional Input-Output Model

The construction cost of a direct-survey based regional I-O model in both temporal and monetary terms is enormous. For this reason, nonsurvey regional I-O models derived from national I-O models are now in common use in the literature. The present paper drives a static, open I-O model for the study region derectly from the U.S. national model by the supply-demand pull method.[3] The 1978 U.S. national model updated from the 1972

3 An I-O system can be represented by 'open' and 'closed' models. The open I-O model is the model with final demand sectors exogenous, while the closed I-O model is the model with final demand sectors endogenous. The clolsed model has better analytical merit than the open model, but it does not lend itself readily to algebraic manipulation since it is completely circular with no exogenous variable. For more on the closed I-O model, see O' Conner, *et al.* (1975) and Yan (1968).

model at the 4-digit SIC level is used[4]. This national model includes 365 endogenous sectors.

The identification of economic sectors is the first step of the model derivation. Industries reported in *the 1978 Ohio County Business Patterns* data for the study region are grouped into 24 endogenous sectors according to the following two categories: (1) industries producing similar and closely related products, and (2) the conformity with the level of aggregation used by the Bureau of Economic Analysis (BEA) in preparing the U.S. national I-O model for 1972. These regional endogenous sectors are listed in Table 1.

The second step of the model derivation is to reduce the national model to reflect the size and structure of the regional economy. The U.S. national model at the 365 sector level is reduced in two steps to include only 24 endogenous sectors identified in the study region (Table 1). First, 118 sectors in the national model with zero production in the study region in 1978 are excluded, but allocated directly to regional noncompetitive imports[5]. Then the remaining 247 sectors are aggregated to a total number of 24 sectors. The aggregation follows the conventional two steps, first the aggresation by row, then the aggregation by column.[6] Resulted is the 24x24 reduced national model.

The third step is to estimate regional transactions from

4 The 1972 U.S. national I-O model is at two different "Standard Industrial Classification (SIC)" levels: 2-digit and 4-digit SIC levels. The model at the 2-digit SIC level includes 85 endogenous sectors (Ritz, 1979) or 97 endogenous sectors (SA, 1981), and the model at the 4-digit SIC level includes 496 endogenous sectors (USDCa, 1979) or 365 endogenous sectors. The 365 sector model is not published, but is available on the computer readable magnetic tape. The model at the 4-digit SIC level is used to correct the possible difference between the regional and national production functions. The input structure in industries at the 4-digit SIC level is more similar throughout the nation than at the 2-digit SIC level. For more on this, see Boisvert (1975).

5 Of the 365 endogenous sectors of the U.S. national I-O model 118 sectors had zero production in the region in 1978. The inputs from these 118 sectors are the noncompetitive imports to the region. Those inputs are not produced in the region, but are employed by the remaining 247 sectors which produce in the region. In order to reflect the pure regional economy these noncompetitive imports must be excluded from the regional transactions. To do so, the 118 sectors are not used in the aggregation, but allocated directly to the regional imports. For more on this, see Ro (1982).

6 In the aggregation by column, the regional employment figures at the 365 sector level of disaggregation are used as sectoral weights to correct the possible difference in the industrial composition between the region and nation. For more on this weighting scheme, see Boisvert *et al.* (1976) and Ro (1982).

Table 1

ENDOGENOUS SECTORS INCLUDED IN THE REGIONAL I-O MODEL FOR THE FIFTEEN MAJOR COAL PRODUCING COUNTIES IN OHIO[1]

Sector	Bureau of Economic Analysis Classification	Standard Industrial Classification
1. Agriculture	1-4	1, 2, 7-9
2. Coal Mining	7	11, 12
3. All Other Mining	8, 9	13, 14
4. Construction	11, 12	15-17
5. Food & Kindred Products	14	20
6. Textile & Apparel	17-19	21-23
7. Lumber & Wood Products	20-25	24-26
8. Printing & Publishing	26	27
9. Chemicals & Plastics	27-32	28-31
10. Stone, Clay & Glass	35, 36	32
11. Primary Metals	37, 38	33
12. Fabricated Metals	39-42	34
13. Mechanical Machinery	43-52	35
14. Electrical Machinery	53-58	36
15. Instruments & Equipments	59-64	37-39
16. Transportation & Warehousing	65	40-42, 44-47
17. Communications	66, 67	48
18. Utilities	68	49
19. Wholesale Trade	69	50, 51
20. Retail Trade	69	52-59, 73, 80
21. Finance, Insurance & Real Estate	70, 71	60-66
22. Services	72-77, 81	58, 70-73, 75, 76, 78-84, 89
23. Federal Government	78	N/A
24. State & Local Government	79	N/A

Source: Various publications of the Ohio Bureau of Employment Services for 1978, *1978 Ohio County Business Patterns, 1978 Ohio Division of Mines Report*, Appendix B in Ritz (1979), Table A in Young, *et. al.* (1979), and USDCa (1979).

[1]N/A = Not Applicable

national transactions. The regional transactions table in its simplest form is outlined in Table 2. The task is then, given the correspondingly aggregated national transactions table and given estimates of regional outputs (X_i) and regional final consumptions (C_f), to estimate regional transactions (x_{ij}), exports (e_i), imports (m_j), and value added (v_j). Or, given the reduced national I-O system

$$(1) \quad X_i^* = \Sigma_j^k \, a_{ij}^* \, X_j^* + \Sigma_f^s \, c_{if}^* + e_i^* \; (i = 1, 2, \ldots, k)$$

plus regional outputs and regional final consumptions, the task is to estimate the regional system

$$(2) \quad X_i = \Sigma_j^k \, a_{ij} \, X_j + \Sigma_f^s \, c_{if} + e_i \; (i = 1, 2, \ldots, k)$$

where a_{ij}^* and a_{ij} are the 24x24 technical coefficients ($a_{ij}^* = x_{ij}^*/X_j^*$, $a_{ij} = x_{ij}/X_j$) in the nation and region respectively, X_i^* and X_i are the i th sector's outputs, c_{if}^* and c_{if} are the final consumptions of

Table 2

THE SIMPLIFIED REGIONAL TRANSACTIONS TABLE

Outputs / Inputs		Purchasing Sectors: Processing Sectors $1, 2, 3, \ldots, k$	Purchasing Sectors: Final Consumption $1 \ldots s$	Exports	Total Outputs
Producing Sectors: Processing Sectors	1	x_{11} x_{12} x_{13} ------ x_{1k}	c_{11} ----- c_{1s}	e_1	X_1
	2	x_{21} x_{22} x_{23} ------ x_{2k}	c_{21} ----- c_{2s}	e_2	X_2
	3	x_{31} x_{32} x_{33} ------ x_{3k}	c_{31} ----- c_{3s}	e_3	X_3
	¦	¦ ¦ ¦ ¦	¦ ¦	¦	¦
	k	x_{k1} x_{k2} x_{k3} ------ x_{kk}	c_{k1} ----- c_{ks}	e_k	X_k
Producing Sectors: Value Added		v_1 v_2 v_3 ------- v_k	u_1 ------ u_s		
Producing Sectors: Imports		m_1 m_2 m_3 ----- m_k	n_1 ----- n_s		
Total Inputs		X_1 X_2 X_3 ------ X_k	C_1 ----- C_s		

s consuming sectors, and e_i^* and e_i are exports. The estimation is accomplished by the supply-demand pool technique[7].

The supply-demand pool techinique is a method of generating the regional transactions table from the national transactions table on the basis of the commodity balance of the regional economy. This approach begins by finding initial estimates of regional transactions ($\hat{x}_{ij}$) and final consumptions ($\hat{c}_{if}$).

$$(3) \quad \hat{x}_{ij} = a^*_{ij} \; X_j$$

$$(4) \quad \hat{c}_{if} = c^*_{if} \, (C_f / C^*_f)$$

where C_f and C_f^* are the total final consumptions of the f th final consumption sector in the region and nation respectively. Note that $X_j = X_i$ for all $i = j$.

Then the commodity balances for individual sectors of the regional economy (b_i) are estimated as

$$(5) \quad \hat{X}_i = \Sigma_j^k \hat{x}_{ij} + \Sigma_f^S \hat{c}_{if}$$

$$(6) \quad b_i = X_i - \hat{X}_i$$

where $\Sigma_j^k \; \hat{x}_{ij}$ and $\Sigma_f^s \; \hat{c}_{if}$ represent the regional total input and consumption requirements from the i th processing sector respectively, and thus $\hat{X}_i$ stands for the regional total output requirements from the sector i. Consequently, b_i is the difference between the sectoral output required in the region ($\hat{X}_i$) and the sectoral output realized in the region (X_i).

The value of b_i must be either positive, zero, or negative. If b_i is positive or zero, regional competitive imports (m_{ij}) are assumed to be zero, the regional technical coefficients are set equal to the

7 To date, a considerable number of attempts have been made to develop nonsurvey techniques of obtaining regional I-O models from national models. Schaffer, et al. (1969) outlined the most salient nonsurvey techniques such as the location quotient technique and its modification, the pool technique and its modification, and the iterative procedure, and on the basis of their comparison went on to conclude that the simple location quotient and supply-demand pool technique provides better regional estimates than others. The use of the simple location quotient needs balancing corrections, while the supply-demand pool approach needs no balancing corrections. For detailes on this, see Schaffer, *et al.* (1969).

national ones, and exports are set equal to the commodity balances.[8]

$$(7) \quad a_{ij} = a^*_{ij}$$

$$(8) \quad x_{ij} = \hat{x}_{ij}$$

$$(9) \quad m_{ij} = 0$$

$$(10) \quad e_i = b_i$$

On the other hand, when b_i is negative, exports are set equal to be zero, and the regional technical coefficients, transactions, final consumptions and competitive imports are computed as follows:

$$(11) \quad a_{ij} = a^*_{ij}\ (X_i/\hat{X}_i)$$

$$(12) \quad x_{ij} = a_{ij}X_j, \text{ or } x_{ij} = \hat{x}_{ij}(X_i/\hat{X}_i)$$

$$(13) \quad c_{if} = \hat{c}_{if}\ (X_i/\hat{X}_i)$$

$$(14) \quad m_{ij} = \hat{x}_{ij} - x_{ij}$$

$$(15) \quad m_{if} = \hat{c}_{if} - c_{if}$$

$$(16) \quad e_i = 0$$

The regional imports (m_j) are computed as the sum of the non-competitive and competitive imports. The regional value added (v_j) is then defined as residuals; i.e., $v_j = X_j - \Sigma_i^k x_{ij} - m_j$. Resulted is the complete I-O transactions table for the study region.

8 The competitive components of the regional imports are the regional goods and services imported from outside the region due to the region's insufficient production capacity. These competitive imports must be excluded from the regional transactions in order to express the pure regional economy.

Multipliers are the primary products of the regional I-O model which enable researchers to identify economic sectors having relatively large impacts on the regional economy. The I-O multipliers are three kinds; output, employment and income multipliers. The output multiplier for a given endogenous sector (λ_j^o) is defined as

$$(17) \quad \lambda_j^o = \Sigma_i^k \; b_{ij}$$

where b_{ij} is the element of the Leontief inverse matrix[9]. This multiplier measures the amount of outputs generated in the region to support a $1 change in final demand in any one sector.

The total change in output of the regional economy resulting from a final demand change in any one sector (ΔX_t) can be estimated as

$$(18) \quad \Delta X_t = \lambda_j^o \; \Delta F_i \,, \quad \forall \; i = j$$

where ΔF_i is a final demand change in a given sector i, and F_i stands for the final demand as the sum of final consumptions and exports; i.e., $F_i = \Sigma_f^s c_{if} + e_i$. This total output change is the sum of output changes in individual sectors (ΔX_i).

$$(19) \quad \Delta X_t = \Sigma_i^k \, \Delta X_i$$

$$(20) \quad \Delta X_i = b_{ij} \; \Delta F_j$$

where $\Delta F_j = \Delta F_i$ for all $i = j$.

9 The regional I-O model may well be represented by
$X = AX + F$, or
$X = (I-A)^{-1}F$
where X is a kx1 vector of regional outputs (X_i), A a kxk matrix of regional technical coefficients (a_{ij}), F a kx1 vector of final demands ($F_i = \Sigma_f^s c_{if} + e_i$). I a kxk identity matrix, and $(I-A)^{-1}$ a kxk matrix of regional interdependence coefficients (b_{ij}), or the Leontief inverse matrix. The interdependence coefficient (b_{ij}) measures total change (direct + indirect) in the requirement of intermediate inputs used by the jth sector as a result of a $1 change in final demand in the ith sector. For more on this, see Miernyk (1965), Yan (1968) and Richardson (1972).

The employment multiplier (λ_j^u) defines the change in total employment in the region resulting from a one-unit change in employment for any one sector.

$$(21)\quad \lambda_j^u = (\Sigma_i^k (U_i / X_i) b_{ij}) / (U_j / X_j)$$

where X_i and U_i are regional outputs and employments repectively, and $U_j = U_i$ and $X_j = X_i$ for all $i = j$. This employment multiplier is used to estimate the employment change in the region (ΔU_t) resulting from a final demand change in any one sector.

$$(22)\quad \Delta U_t = \Delta F_j \ (U_j / X_j) \ \lambda_j^u$$

where $U_j = U_i$, $X_j = X_i$, and $\Delta F_j = \Delta F_i$ for all $i = j$. The employment changes in individual sectors (ΔU_i) are estimated as

$$(23)\quad \Delta U_i = \Delta F_j \ (U_i / X_i) \ b_{ij}$$

where $\Delta F_j = \Delta F_i$ for all $i = j$. Note that $\Delta U_t = \Sigma_i^k \Delta U_i$.[10]

The income multiplier (λ_j^y) measures the total change in income throughout the regional economy resulting from a $1 change in income in a given sector in response to a final demand change in that sector.

$$(24)\quad \lambda_j^y = (\Sigma_i^k (Y_i / X_i) b_{ij}) / (Y_j / X_j)$$

where Y_i stands for regional incomes, and $Y_j = Y_i$ and $X_j = X_i$ for all $i = j$. For a given final demand change in any one sector, the change in income in the region (ΔY_t) and in individual sectors (ΔY_i) are estimated as

10 From equation 21, the total change in employment per unit of final demand is obtained as

$$\lambda_j^u (U_j / X_j) = \Sigma_i^k (U_i / X_i) \ b_{ij}$$

Therefore, equation 22 can be restated as

$$\Delta U_t = \Delta F_j \ \Sigma_i^k (U_i / X_i) \ b_{ij}$$

$$(25)\quad \Delta Y_t = \Delta F_j \, (Y_j / X_j) \, \lambda_j^y$$

$$(26)\quad \Delta Y_i = \Delta F_j \, (Y_i / X_i) \, b_{ij}$$

where $Y_j = Y_i$, $X_j = X_i$, and $\Delta F_j = \Delta F_i$ for all $i = j$. Note that

$\Delta Y_t = \Sigma_i^k \Delta Y_i$.[11]

Equations 20, 23 and 26 are used to estimate changes in output, employment and income in individual sectors resulting from a final demand change in the coal mining sector in response to the enforcement of the sulfur emission control imposed on the use of coal in energy applications. The estimated changes are considered as economic impacts of the sulfur emission control on individual sectors within the regional economy.

IV. Empirical Results

This section presents results from the economic impact analysis of the sulfur emission control. For a better understanding of the results, an overview of the study region's conomy in terms of output, employment and income and the identification of regional high impact potential sectors through the regional I-O multiplier analysis are presented first.

Output, Employment and Income

The sectoral output, employment and income figures are pre-

11 From equation 24, the total change in income per unit of final demand is obtained as

$$\lambda_j^y (Y_j / X_j) = \Sigma_i^k (Y_i / X_i) \, b_{ij}$$

By substituting this equality, equation 25 can be restated as

$$\Delta Y_t = \Delta F_j \quad \Sigma_i^k (Y_i / X_i) \, b_{ij}$$

sented in Table 3.[12] In 1978, the regional economy generated $16.4 billion of output and $4.3 billion of income, and had 331 thousand man-years of employment. An average employee in the region produced $49,680 of output and earned $13,005 of income in 1978.

Table 3

SECTORAL OUTPUT, EMPLOYMENT, AND INCOME FOR THE STUDY REGION, 1978

Sectors	Output ($ million)	Employment (man-years)	Income ($ million)
Agriculture	347.7	8,634	70.2
Coal Mining	697.4	12,634	251.0
All Other Mining	290.7	2,627	37.2
Construction	94.6	9,973	170.6
Food & Kindred Products	823.9	5,890	76.9
Textile & Apparel	94.1	2,111	21.0
Lumber & Wood Products	370.1	6,866	89.6
Printing & Publishing	130.5	4,534	61.3
Chemicals & Plastics	1,061.1	10,592	162.6
Stone, Clay & Glass	364.9	10,995	158.5
Primary Metals	3,010.6	30,987	577.4
Fabricated Metals	748.6	12,328	182.1
Mechanical Machinery	866.7	17,477	268.5
Electrical Machinery	444.3	8,839	119.4
Instruments & Equipment	295.8	4,225	62.2
Transportation & Warehousing	317.5	6,719	108.2
Communications	120.3	3,352	54.3
Utilities	862.2	5,366	91.5
Wholesale Trade	441.4	13,062	181.6
Retail Trade	526.8	40,214	342.8
Finance, Insurance & Real Estate	802.1	11,543	125.6
Services	2,770.4	58,385	81.1
Federal Government	22.3	3,210	58.5
State & Local Government	99.6	40,025	447.3
Total	**16,423.6**	**330,588**	**4,299.3**

Sources: USDC (1980), OARDC (1979). USDCb (1979), ODIR (1979) and OBESa (1979)

12 Except for the agricultural and coal mining sectors, the regional outputs for all sectors were computed as the national productivity of labor multiplied by the regional employment. The output for the agricultural sector was obtained from *Ohio Farm Income*

That the region is dependent on a few sectors in employment is evident from Table 3. The top five sectors in employment are the services, retail trade, state and local government, primary metals and mechanical machinery sectors. These sectors together account for more than 56% of regional total employment. In addition, the wholesale trade, coal mining, fabricated metals, finance and stone sectors are ranked high in terms of employment. These five sectors share an additional 18% of regional total employment.

The top ten sectors in output are the primary metals, services, chemicals, utilities, mechanical machinery, food, finance, fabricated metals, coal mining and construction sectors. These sectors account for more than two-thirds of regional total output. In terms of income, the top ten sectors are the services, primary metals, state and local government, retail trade, mechanical machinery, coal mining, fabricated metals, wholesale trade, construction and chemicals sectors accounting for more than three-quarters of regional total income.

In short, the regional economy appears to be largely dependent on the primary metals, fabricated metals, mechanical machinery, coal and services sectors. These five sectors are included in the group of the top ten sectors in all the rankings of output, employment and income. On the average, they together account for more than one half of regional total output, employment and income.

Regional High Impact Potential Sectors

In Table 4 are provided sectoral multipliers for output, employment and incomes. Output multipliers are presented in the first column with their ranks. The output multiplier measures the amount of output directly and indirectly generated within the

(OARDC, 1979), and the output for the coal mining sectors from *Ohio Division of Mines Report* (ODIR, 1979). The employment for the agricultural sector was estimated as the sectoral output devided by the national per capita agricultural productivity. The employment figure for the coal mining sector was obtained directly from *Ohio Division of Mines Report* (ODIR, 1979). The employment figures for the remaining sectors were obtained from Ohio County Business Patterns data on tape (USDC, 1980). The regional income for all sectors was estimated as the sectoral employment multiplied by the sectoral average annual earnings in the region. The sectoral average annual earnings were obtained through Ohio Bureau of Employment Services (OBESb, 1979).

regional economy by a $1 change in final demand for the output of a particular sector. For example, the output multiplier for the instruments sector is the highest at 1.98. This means that a $1 change in final demand for the output of the instruments sector will cause the highest change in total output of $1.98 in the regional economy.

Table 4

OUTPUT, EMPLOYMENT, AND INCOME MULTIPLIERS OF THE REGIONAL ENDOGENOUS SECTORS, 1978

Sectors	Multipliers[1] Output	Employment	Income
Agriculture	1.68 (12)	1.50 (13)	1.67 (12)
Coal Mining	1.42 (18)	1.38 (16)	1.34 (18)
All Other Mining	1.38 (19)	1.67 (11)	1.65 (13)
Construction	1.79 (10)	1.91 (6)	1.71 (11)
Food & Kindred Products	1.97 (2)	3.54 (1)	3.09 (1)
Textile & Apparel	1.34 (20)	1.29 (19)	1.36 (16)
Lumber & Wood Products	1.81 (8)	1.74 (9)	1.79 (8)
Printing & Publishing	1.61 (13)	1.36 (17)	1.35 (17)
Chemicals & Plastics	1.80 (9)	2.16 (4)	2.08 (4)
Stone, Clay & Glass	1.56 (15)	1.30 (18)	1.30 (19)
Primary Metals	1.86 (5)	2.18 (3)	2.00 (5)
Fabricated Metals	1.94 (3)	1.81 (8)	1.85 (7)
Mechanical Machinery	1.84 (6)	1.66 (12)	1.64 (14)
Electrical Machinery	1.89 (4)	1.70 (10)	1.75 (10)
Instruments & Equipment	1.98 (1)	2.09 (5)	2.09 (3)
Transportation & Warehousing	1.53 (16)	1.48 (14)	1.40 (15)
Communications	1.30 (21)	1.21 (20)	1.17 (22)
Utilities	1.74 (11)	2.70 (2)	2.60 (2)
Wholesale Trade	1.30 (22)	1.20 (21)	1.18 (21)
Retail Trade	1.29 (24)	1.07 (24)	1.10 (23)
Finance, Insurance & Real Estate	1.61 (14)	1.86 (7)	2.00 (6)
Services	1.50 (17)	1.41 (15)	1.52 (14)
Federal Government	1.29 (23)	1.09 (23)	1.06 (24)
State & Local Government	1.83 (7)	1.14 (22)	1.18 (20)
Whole Economy	**1.63**	**1.68**	**1.65**

Source: Computed through the regional I-O model.
1 Figures in the parenthesis are ranks of multipliers.

The output multiplier is relatively large in the food, fabricated metals, electrical machinery, primary metals, mechanical machinery, state and local government, lumber, chemicals and construction sectors. A final demand change in any one of these sectors would have a relatively large effect on the output throughout the regional economy. The output multiplier for the regional economy as a whole was estimated to be 1.63 indicating that every $1 change in final demand generates, on the average, an output change of $1.63 in the regional economy.

Employment multipliers with their ranks are presented in the second column. The employment multiplier measures the total employment change in man-years generated in the regional economy as a result of an aditional man-year to the employment of a particular sector in response to a final demand change in that sector. For instance, a one man-year change in employment in the food sector would generate the highest employment of 3.54 man-years in the regional economy. In addition to the food sector, the utilities, primary metals, chemicals, and instruments sectors have employment multipliers greater than 2.00. An employment change in any one of these sectors would have a relatively large impact on the employment throughout the regional economy. The employment multiplier of 1.68 was estimated for the regional economy as a whole.

The income multiplier measures the total change in income throughout the regional economy that results from a $1 change in income in a particular sector in response to a final demand change in that sector. In the last column of Table 4 are shown income multipliers with their ranks. The interpretation of the income multiplier is analogous to that for the employment multiplier. For example, the income multiplier is the largest in the food sector at 3.09 indicating that a $1 increase in that sector's income will generate the highest additional income of $3.09 in the regional economy. The income multiplier is also relatively large for the utilities, instruments, chemicals, primary metals and finance sectors. An income change in any one of these sectors would have a relatively large effect on the income throughtout the regional economy. The income multiplier for the regional economy as a whole was estimated to be 1.65.

The analysis of multipliers enables the identification of regional high impact potential sectors. The high impact potential sector refers to a sector whose expansion (or contraction) has a relatively large, postitive (or negative) effect on the regional economy. The multiplier measures the impact of expansion (or contraction) of a given sector on the regional economy. Thus the sectors with relatively large multipliers can be considered as the high impact potential sectors of the regional economy,

Since the economic problems of the study region are high unemployment and low per capita income, relatively more attention should be on the employment and income multipliers in order to identify the high impact potential sectors of the regional economy. The top ten sectors ranked by the employment multiplier are the food, utilities, primary metals, chemicals, instruments, construction, finance, fabricated metals, lumber and electrical machinery sectors. These sectors are also found in the group of the top ten sectors ranked by the income multiplier. Consequently, these large income and employment multiplier sectors are identified as the regional high impact potential sectors in the sense that expanding any one of those sectors would result in a relatively large increase in both employment and income throughout the regional economy.

Impacts of the Sulfur Emission Control

As mentioned earlier, an annual decline in the demand for Ohio coal of 3.1 million tons is expected due to the enforcement of the sulfur emission control. This decline accounts for 7.5% of the Ohio total coal produced in 1978, and is equivalent to a $52.3 million reduction in the demand for coal produced in the study region. Effects of this reduction on each endogenous sector's output, employment and income are estimated through equations 20, 23 and 26. The estimation results are presented in Table 5 to represent the economic impact of the sulfur emission control.

In the first column are shown the estimated decreases in each sector's output. The estimated decrease in output is the largest in the coal mining sector at $59,590.3 thousand followed by the mechanical machinery ($2,664.8 thousand), chemicals ($2,249.2 thousand), services ($1,863.7 thousand), primary metal ($1,642.7 thousand), utilities ($1,281.8 thousand), and finance ($1,023.6 thousand) sectors. The expected output decrease in the region as a whole was estimated to be $74.2 million accounting for about .45% of the regional total output.

Table 5

EXPECTED DECREASES IN OUTPUT, EMPLOYMENT AND INCOME OF THE REGIONAL ENDOGENOUS SECTORS, DUE TO THE ENFORCEMENT OF THE SULFUR EMISSION CONTROL, 1978

Sectors	Output ($1,000)	Employment (man-years)	Income ($1,000)
Agriculture	68.0	1.7	13.7
Coal Mining	59,590.3	1,086.2	21,585.7
All Other Mining	234.1	2.1	30.0
Construction	372.8	6.2	107.0
Food & Kindred Products	137.4	1.0	12.8
Textile & Apparel	18.1	.4	4.0
Lumber & Wood Products	319.5	5.9	77.4
Printing & Publishing	64.2	2.2	30.2
Chemicals & Plastics	2,249.2	22.3	344.1
Stone, Clay & Glass	227.2	6.8	98.7
Primary Metals	1,642.7	16.8	314.9
Fabricated Metals	759.2	12.5	184.6
Mechanical Machinery	2,664.8	54.4	834.1
Electrical Machinery	212.7	4.0	57.0
Instruments & Equipment	84.2	1.2	17.7
Transportation & Warehousing	346.2	7.3	117.9
Communications	76.9	2.1	4.7
Utilities	1,281.8	7.7	15.9
Wholesale Trade	843.8	24.9	347.1
Retail Trade	34.6	2.6	22.5
Finance, Insurance & Real Estate	1,023.6	14.3	660.3
Services	1,863.7	39.1	389.5
Federal Government	51.8	3.2	58.0
State & Local Government	13.9	1.4	15.6
Total[1]	**74,180.2**	**1,326.3**	**24,993.4**

Source: Computed through the regional I-O model.

1 The sun of the elements in each column may not be equal to the respective column total due to the rounding error.

The last two columns present the estimated decrease in each sector's employment and income. The enforcement of the sulfur emission control results in an employment loss of 1,086 man-years in the coal mining sector, 54 man-years in the mechanical machinery sector, 39 man-years in the services sector, 25 man-years in the wholesale trade sector, and 22 man-years in the chemicals sector. With respect to income, the estimated decrease is relatively large in the coal mining ($21,585.7 thousand), mechanical machinery ($834.1 thousand), services ($389.5 thousand), wholesale trade ($347.1 thousand), chemicals ($344.1 thousand), and primary metals ($314.9 thousand) sectors. The regional total decrease in employment and income was estimated to be 1,326 man-years and $25.0 million, respectively.[13] These respective figures account for about .40% of the regional total employment and about .58% of the regional total income.

In sum, the coal mining sector appears to bear a major portion of economic impacts of sulfur emission control. The coal mining sector alone accounts, on the average, for more than four-fifths of regional total decreases in output, employment and income. In addition to the coal mining sector, economic impacts of the sulfur emission control are relatively large on the chemicals, primary metals, mechanical machinery, utilities, finances, services, fabricated metals and wholesals trade sectors, and most of these are the regional high impact potential sectors. However, economic impacts on the regional economy as a whole appear to be minor. The estimated regional total decrease in output amounts less than 1% of the regional total output. This minor impact is also true with respect to employment and income.

As a result of the enforcement of the sulfur emission control changes in output may also occur in other sectors than the coal mining sectors. For example, improved air quality resulting from the enforcement of the sulfur emission control may cause positive changes in some sectors. These possible changes, however, were not considered in the economic impact analysis of the sulfur emission control due to their intangible nature. Consequently, the estimates used in the impact analysis remain conservative.

V. Concluding Remarks

In this paper, a nonsurvey, static, open I-O model was deriv-

13 As mentioned earlier, Schweers, *et al.* (1979) and TBS (1974) estimated a loss of 910 jobs in the coal mining industries and 1,140 jobs in other related industries as a result of the enforcement of the sulfur emission control. These respective estimates are larger than the present estimates. This is primarily because their estimates are for the whole state of Ohio. Note that the present estimates are for a subregion (the study region) of the state.

ed for the region of fifteen coal producing counties in Ohio directly from the U.S. national I-O model. This regional model including 24 endogenous sectors was used to estimate the economic impact of the sulfur emission control imposed on the use of coal in energy applications.

The imposition of the sulfur emission control seems to justify the environmental concern of the public. Economic impacts of the sulfur emission control are minor on the regional economy as a whole. The macro implication is that the negative environmental impact of the use of coal in energy applications can be adequately controled at a marginal cost to the coal producing region's economy. However, economic impacts of the sulfur emission control are considerably large in the coal mining and related high impact potential sectors. The relaxation or enforcement of the sulfur emission control therefore remains as an important policy variable in dealing with the coal producing region's economic problems of high unemployment and low income.

It is felt that the regional I-O analysis should continue to be expanded to incorporate the environmental concern of the public. The estimation of economic impacts of the sulfur emission control is an example of this expansion. Given the best available estimates of the associated changes in current levels of sectoral output, the regional I-O analysis appears to be very useful in estimating and evaluating economic impacts of any envionmental regulations.

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