REGIONAL ENVIRONMENTAL QUALITY: AN OPTIMAL INDUSTRY MIX TO MINIMIZE POLLUTION

T. C. Meadows and J. C. Hite*

Mars Hill College and Clemson University

Recreation and leisure-oriented industry is frequently recommended as a type of economic development suitable for rural, low-income areas interested in preserving a high quality natural environment. However, even such activities as these have negative aspects -- both economic and environmental -- which are not generally recognized. In this paper, evidence will be presented showing that even the most innocuous appearing industries may have serious environmental impact. While this evidence is based on two case studies and should not be generalized too broadly, it does serve to alter regional development planners to some of the special problems associated with the development of tourism as part of a regional economic base.

Recent concern over environmental problems has produced a body of literature attempting to expand the traditonal concepts of economics to account for environmental externalities. The suggestion for a general model to encompass the entire natural environment as it interrelates with economic activity was presented by Kenneth Boulding in his famous "Spaceship Earth" article in 1966 (3). Other research by Ayres and Kneese (1), Isard and his associates (7, 8) and Hite and Laurent (6) has broken new ground, both conceptually and empirically, in linking economic and ecologic systems within a regional economy.

Such works provided a stimulus for the present report which is an outgrowth primarily of the work of Hite and Laurent in the Charleston-Beaufort County area of South Carolina. The analysis presented in this paper is based upon empirical data collected in the Charleston-Beaufort County area. Linear programming is the analytic technique used. The prime concern of this paper is the environmental impact of economic development based upon tourism.

Data are presented in Tables 1 and 2 which show the projected effects of one hundred export jobs in five types of economic activities upon the Charleston and Beaufort County Areas. The figures in the tables were obtained by expounding an E matrix to include coefficients on personal income, number of jobs, and tax revenues per dollar by gross sales for each sector in the input-output matrix developed by Hite and his associates in their study of the Charleston-Beaufort County area.

THE LINEAR PROGRAMMING MODEL

Although the information reported in Tables 1 and 2 might be used in its raw form as an input into planning decisions, this information is adaptable to use in a linear programming model. Linear programming lends itself to an analysis of this type because of its relative simplicity and generality. For planning and policy purposes, linear programming can be quite useful because the goal of regional or development planning as a rule envisions some varia-

*Professor T. C. Meadows is an Assistant Professor of Economics at Mars Hill College in Mars Hill, North Carolina. Professor J. C. Hite is a Associate Professor of Agricultural Economics, Clemson University in Clemson, South Carolina.

tions upon the present combination of the variables involved. Determination of the optimal solution to problems involving various combinations is the forte of linear programming. Baumol (2, p. 71) has pointed out that linear programming has been "... somewhat less successful in describing what is than in indicating what ought to be." From previous studies we know what "is" in the Charleston-Beaufort County area. What we are interested in is discovering what "ought to be" to have economic growth yet preserve the environment.

Linear programming is essentially a mathematical technique for maximizing or minimizing some variable, given a set of constraints which must be met (11). Thus, linear programming might be used to determine the optimum mix of industries in the coastal zone of South Carolina, given that the goal was to minimize pollution, subject to a set of economic constraints relative to minimum allowable levels of income, jobs, tax revenues, etc. The information reported in Tables 1 and 2 could be used to obtain the coefficients necessary for writing such a linear programming model.

Suppose, for example, it was decided that the planning goal for the South Carolina coastal zone was to minimize the 5-day BOD emissions. We could write an objective function to be minimized based on information in line eight of Tables 1 and 2. Obviously, the easiest way to minimize the BOD residuals in the coastal zone would be to declare the whole area off limits to all types of economic activity. But such an easy course of action begs the question because the coastal zone of South Carolina is populated and that population must earn a livelihood. Consequently, we will probably want to minimize BOD residuals subject to some constraints. If we desire to place a floor under personal income in the coastal zone, we can use information from line two in Tables 1 and 2; if we desire to assure full employment, we can obtain information from line three; and if we desire to hold tax revenues to some minimum level, we can use information from lines four and five. Thus, Tables 1 and 2 give us the information we need to write a linear programming model for obtaining an optimum mix of industries in the Charleston and Beaufort areas:

One practical linear programming model for the coastal zone might be to minimize total BOD residuals, subject to:

(1) generation of enough jobs to fully employ the labor force in both the Charleston and Beaufort areas,

(2) generation of enough personal income to bring per-capita income in the two areas up to the national average,[1]

(3) generation of enough local and county tax revenue to adequately support local services, and

(4) assurance that no existing industry would be shut-down or forced to cut back its employment.

With only a few pieces of additional data on population, per-capita incomes, etc., there is enough information in Tables 1 and 2 to write such a linear programming problem.

But the actual writing of equations for constraints 2 and 3 poses some problems. These constraints must be dynamic. In constraint 2, for example, the total personal income must be great enough to yield the national average per-capita income when divided by the local population. If the total number of jobs created exceed the local labor supply, one would assume in-migration which will raise the local population. Thus, as the population increases, the total amount of personal income must also increase if per-capita income in the area is to be at least equal to the national average. Given that we know that about one person out of every 3.874 in the local population in the Charleston and Beaufort areas is a member of the labor force, and that the national per-capita income in 1969 was \$3,676, constraint 2, written as inequalities (one each for Charleston and Beaufort areas), then becomes:

$$1,123,400X_1 + 1,642,200X_3 + 1,262,900X_5 + 1,797,500X_7 + 1,943,400X_9 \geq$$
$$3,676 \left[3.874(125X_1 + 136X_3 + 125X_5 + 143X_7 + 149X_9) \right]$$

and

$$179,400X_2 + 1,147,200X_4 + 982,800X_9 + 1,288,600X_8 + 1,493,600X_{10} \geq$$
$$3,676 \left[3.874(111X_2 + 119X_4 + 114X_6 + 118X_8 + 126X_{10}) \right],$$

where:

X_1 = hundreds of workers employed in food and kindred products at Charleston,

X_2 = hundreds of workers employed in food and kindred products at Beaufort,

X_3 = hundreds of workers employed in textiles and apparel at Charleston,

X_4 = hundreds of workers employed in textiles and apparel at Beaufort,

X_5 = hundreds of workers employed in lumber and wood products (including pulp and papers) at Charleston,

X_6 = hundreds of workers employed in lumber and wood products (including pulp and paper) at Beaufort,

X_7 = hundreds of workers employed in chemicals at Charleston,

X_8 = hundreds of workers employed in chemicals at Beaufort,

X_9 = hundreds of workers employed in tourism at Charleston, and

X_{10} = hundreds of workers employed in tourism at Beaufort.

Then simplifying these inequalities, we get:

$$-656,887X_1 - 294,684X_3 - 503,050X_5 - 239,004X_7 - 178,387X_9 \geq 0$$

and

$$-901,280X_2 - 547,436X_4 - 641,992X_6 - 391,331X_8 - 330,288X_{10} \geq 0$$

Upon examination of these inequalities, the reader familiar with only basic mathematics will realize that it is impossible for the sum of a series of negative numbers to be equal to, or greater than, zero. Consequently, we must conclude that the income constraint which we wish to impose is not realistic. The five basic industries being examined in this study cannot bring per-capita income in the Charleston and Beaufort areas to the national average, regardless of how large their activities are allowed to become. As a group, these industries use relatively large amounts of labor (thus requiring a relatively large population to supply labor) and generate relatively low amounts of income. A similar mathematical exercise concerning constraint 4 will yield the same conclusion.[2]

Although it is not feasible to include constraints on income and tax revenues in the linear programming model suggested above, there are no special difficulties associated with constraints 1 and 4. It may be useful to continue development of the model with these constraints. Accordingly, a linear programming problem was formulated so that we:

$$\text{Minimize: } \emptyset = 250,900X_1 + 335,100X_2 + 324,400X_3 + 470,200X_4 + 1,644,100X_5 + 1,736,000X_6 + 149,300X_7 + 249,300X_8 + 39,800X_9 + 131,100X_{10}$$

Subject to:

(1) $125X_1 + 136X_3 + 124X_5 + 143X_7 + 149X_9 \geq 58,763$

(2) $111X_2 + 119X_4 + 1114X_6 + 118X_8 + 126X_{10} \geq 13,200$

(3) $X_1 \geq 16.00$

(4) $X_2 \geq 3.50$

(5) $X_3 \geq 33.64$

(6) $X_4 \geq 2.50$

(7) $X_5 \geq 43.36$

(8) $X_6 \geq 1.00$

(9) $X_8 \geq 1.00$

(10) $X_{10} \geq 6.92$

where:

$\emptyset$ = Total 5-day BOD emissions in both the Charleston and Beaufort areas and all other notation is as previously defined.

The first two inequalities in this problem require that the total number of jobs created in the Charleston and Beaufort areas be at least equal to the labor forces in the two areas, respectively. The last eight inequalities require that no current activity in the two areas, except Charleston area chemicals and tourism at Beaufort, be reduced to lower than current levels of employment. Charleston area chemicals were omitted from these constraints because most of the existing facilities at Charleston are old and somewhat antiquated, so that these facilities could be gradually closed without sacrifice of significant fixed assets. Tourism at Beaufort was omitted because it produces relatively low amounts of BOD per worker and was considered likely to be included in an optimum solution at a level of about current employment.

The solution to this linear programming problem is shown in Table 3. Tourism emerges as the major employer in both areas in this optimum solution; 31,417 persons would be employed in tourism in the Charleston area and 9,748 in the Beaufort area. Such a solution is to be expected if one observes in Tables 1 and 2 that tourism produces the least BOD per hundred workers inducing the greatest number of outside jobs of any of the five alternatives. All the other activities are shown in Table 3 at the levels required by inequalities 3-10 in the mathematical formulation of the problem.

EVALUATION OF RESULTS

Table 4 shows the economic and environmental ramifications of the optimum solution presented in Table 3. Line 3 in Table 4 shows that per-capita income in both areas is below the national average, but perhaps the most striking feature of Table 4 is that per-capita income in Beaufort County is about one-third greater than at Charleston in the optimum solution. Since the military activities were not considered as alternatives in the linear programming problem, per-capita income at Charleston in the optimum solution is actually about $300 less per year than the per-capita income prevailing at Charleston in 1968. Total sales at Charleston is also lower in the optimum solution than the 1968 level; the 1968 level was $2,232,000,000- the optimum solution level is $1,167,074,000. Per-capita income in the Beaufort area is about $450 per year greater in the optimum solution than in 1969 per-capita income in that county (5, p. 12); although, even at Beaufort, total sales are reduced by the optimum solution from the estimated 1969 level of $245,972,000 (5, p. 13). It is apparent, therefore, that any policy designed to minimize BOD residuals, constrained only by a requirement that the labor force be fully employed, will require a considerable reduction in the level of economic activity at Charleston and a slight reduction in the level of economic activity at Beaufort. Moreover, it is also apparent that such a policy will reduce per-capita income in the Charleston area.

School expenditures normally take up to as much as one-half of local tax revenues in South Carolina. The statewide average expenditure per pupil in South Carolina in 1969-1970 was $214 (5, p. 8). If we allocate one-half of line 4 in Table 3 (Local and County Tax Revenue) for schools and divide by the number of public school pupils in each of the two areas, we will see that the optimum solution determined from our linear programming problem produces only about $70 per year per pupil. Of course, local governments could spend more than one-half of their tax revenues on schools, but to do so they would be forced to cut back on other services. Even if all of the local and county tax revenues in these two areas were spent on schools, however, the linear programming solution would provide only about $140 per pupil per year, a figure far short of the statewide average. Thus, it appears that a policy aimed at minimizing BOD residuals consistent with full-employment will force drastic cutbacks in local expenditures for education in the Charleston and Beaufort areas.

The burden of the analysis in the two paragraphs above is that policy regulating discharge of emissions into the coastal zone of South Carolina must consider a wide range of economic constraints. Full employment is a legitimate goal, but other economic criteria must also be considered. The existing economic base is not strong enough to raise per-capita incomes to the national average, or to raise per-pupil school expenditures to the statewide average, even when no environmental factors are considered. In the long run, that economic base can be broadened and strengthened. But in the short run, policy aimed at minimizing BOD emissions (and probably other types of residuals) will necessitate considerable economic sacrifice.

CONCLUSION

Perhaps the most important point documented by this research is the conflict between area economic well-being, as measured by per-capita income, number of jobs, and tax revenues and environmental quality, as measured by outputs of residuals into the eco-system. Although all the analysis in this paper is based on waste-treatment technology which may be antiquated, it is clear that economic activity will produce waste and that waste must eventually find its way back into the environment. The only way to have a "natural" eco-system in the coastal zone of South Carolina or anywhere else is to exclude economic activity altogether. Since there are people living in the study area, and since those people must have a source of livelihood, excluding economic activity from the study areas will require moving the current population to the interior. Such a drastic remedy is not realistic. Therefore, economic growth and development must be based on allowance of some tolerable levels of waste emissions into our economic-systems. The real question is: What kinds of economic activities will give us the minimum level of environmental damage while providing necessary economic support for the residents of the coastal areas and the people of the State? This research has not answered that question, but it has made a start toward an answer.

Table 1. PROJECTED EFFECTS OF 100 "EXPORT" JOBS IN FIVE TYPES OF ECONOMIC ACTIVITIES ON THE CHARLESTON (SOUTH CAROLINA) METROPOLITAN AREA ECONOMY, 1968

Type of Impact	Given 100 "Export" Workers in: Food & Kindred Products	Textiles and Apparel	Lumber and Wood Products	Chemicals	Tourism
Total Sales ($)	2,088,400	2,694,600	2,433,100	3,001,000	2,984,100
Total Personal Income ($)	1,123,400	1,642,200	1,262,900	1,797,500	1,943,400
Total Number of Jobs	125	136	124	143	149
Local & County Taxes ($)	12,900	77,100	15,300	35,000	22,000
State Taxes ($)	92,500	138,100	154,500	120,100	175,500
Particulates (lbs/yr)	19,200	18,100	1,561,700	21,600	42,500
SO_2 (lbs/yr)	6,200	6,000	4,500	5,600	16,000
5-Day BOD (lbs/yr)	250,900	324,400	1,644,100	149,300	39,800
Solid Waste (cu yds/yr)	900	2,200	153,000	2,500	4,000

Source: Computed using the Hite-Laurent model and output levels reported in Appendix Table IV, Economic Evaluation of Zoning Alternatives in the Management of Estuarine Resources in South Carolina.

Table 2. PROJECTED EFFECTS OF 100 "EXPORT" JOBS IN FIVE TYPES OF ECONOMIC ACTIVITIES ON THE BEAUFORT COUNTY (SOUTH CAROLINA) ECONOMY, 1969

Type of Impact	Given 100 "Export" Workers in: Food & Kindred Products	Textiles and Apparel	Lumber and Wood Products	Chemicals	Tourism
Total Sales ($)	1,030,800	1,895,900	2,003,100	2,157,700	2,309,500
Total Personal Income ($)	679,400	1,147,200	982,800	1,288,600	1,493,600
Total Number of Jobs	111	119	114	118	126
Local & County Taxes ($)	5,100	71,200	11,800	27,000	12,500
State Taxes ($)	65,900	113,800	138,400	94,800	151,400
Particulates (lbs/yr)	2,900	4,700	1,552,200	4,100	19,200
SO_2 (lbs/yr)	4,600	3,500	3,500	3,900	17,300
5-Day BOD (lbs/yr)	335,100	470,200	1,736,000	249,300	131,100
Solid Waste (cu yds/yr)	3,500	6,900	156,300	5,400	7,600

Source: Computed using the Hite-Laurent model and output levels reported in Appendix Table IV, Economic Evaluation of Zoning Alternatives in the Management of Estuarine Resources in South Carolina.

Table 3. OPTIMUM EMPLOYMENT TO MINIMIZE BOD SUBJECT TO FULL EMPLOYMENT AND EXISTING SIZE OF INDUSTRY CONSTRAINTS FOR FIVE SELECTED BASIC ACTIVITIES, CHARLESTON AND BEAUFORT AREAS, SOUTH CAROLINA, 1968-1969

	Employment at:	
Activity	Charleston (3 County Area)	Beaufort County
Food & Kindred Products	1,600	350
Textiles & Apparel	3,364	250
Lumber & Wood Products	4,336	100
Chemicals	-	100
Tourism	31,417	9,748

Source: Computed by linear programming.

Table 4. ECONOMIC AND ENVIRONMENTAL RAMIFICATIONS OF LINEAR PROGRAMMING SOLUTION OF OPTIMUM INDUSTRY MIX, CHARLESTON AND BEAUFORT AREAS, SOUTH CAROLINA, 1968-1969

Type of Impact	Charleston Area	Beaufort County
Total Sales ($)	1,167,074,700	211,318,800
Total Personal Income ($)	738,535,300	153,113,400
Per Capita Income ($)	2,000	3,000
Total Number of Jobs	58,763	13,200
Local & County Taxes ($)	10,375,200	1,453,200
State Taxes ($)	67,958,300	15,506,800
Particulates (lbs/yr)	81,983,600	3,449,800
SO_2 (lbs/yr)	5,522,900	1,718,700
5-Day BOD (lbs/yr)	98,719,400	17,113,300
Solid Waste (cu yds/yr)	7,979,200	932,000

Source: Computed by use of data in Tables 1 and 2.

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