DATA AND MODELS FOR EFFECTIVE RESEARCH AND DEVELOPMENT IN POLLUTION CONTROL

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The quality of our environment is of great concern in our society today. Hence, we are personally and academically concerned. One general topic is directed toward "The Economics of Pollution Control." I much prefer to approach this subject from the point of view of the optimist and define our orientation as that of opportunity and positive attitude toward our environment. Thus, we approach the subject in terms of the quality of our environment, rather than in terms of pollution control. The shock effects, from discussing pollution, have registered with most of us so we can proceed with the opportunity to improve the quality of our environment.

P. H. McGauhey relates the following incident which will identify our problems in the economics of environmental quality [12, p. 5].

"More than half a century ago a Mississippi jurist said, 'It is not necessary to weigh with care the testimony of experts–any common mortal knows when water is fit to drink.' Yet today we find it necessary to assemble, each in the role of both expert and common mortal, to consider just how it is that we know when water is fit to drink. Moreover in the intervening years interest in the fitness of water has gone beyond the health factor and we are forced to decide on its suitability for a whole spectrum of beneficial uses involving psychological and social as well as physiological goals. The dilemma of water quality today is that quality is an attribute that must be measured."

McGaughey's concern with the measurements of quality of water is equally applicable to air, land, flora and fauna which comprise our natural resources and which are the basic components of the environment. Much of the knowledge and concern for environmental quality grew out of earlier concern for the quality of water. It is inevitable that attention will be focused on the quality of water as much as on the quality of the whole environment. It is indeed difficult to deal with the whole environment in a quantitative analysis because of its complexity. We must first solve some smaller equations for subsystems of the environment, such as water, air, or land, or small regions.

Environmental quality is a term which describes the composite chemical, physical, biological, economic, social, and sensual characteristics of our natural resources with respect to their suitability for a specific use. For clarity, we should also provide the obverse definition for water, air, and land pollution. A definition of pollution for legal, economic, and policy implications rests on the activities of man which result in the unreasonable impairment of the value of the resource for a subsequent user.

Unreasonable impairment can be defined only as those human activities which affect the resource in a manner sufficient to interfere with the safety, health, or comfort of subsequent users, or which deprive subsequent users of the full use and enjoyment of his property. The key terms for economists to observe in research on environmental quality are the concepts of "subsequent users" and "impairment." In the first instance, the economist is concerned only when there are "subsequent users." The concept of impairment connotes gradations on a scale wherein absolute values are not meaningful.

Herfindahl and Kneese [9, p. vi] in the preface to their book, *Quality of the Environment,* state that ". . .it is economics alone that can formulate these (quality of the environment) problems in the terms to which they must finally be reduced, namely the balancing of our varied desires in these matters against the costs of satisfying them in various degrees." However, Herfindahl and Kneese do admit that the collaboration of scientists from other disciplines would be required for useful analyses and applications.

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Our approach to research in environmental quality must be interdisciplinary in terms of the chemical, physical, biological, and engineering fields. At first, interdisciplinary research seems as impossible as discussing simultaneously the data sources and models for pollution research in one short article. However, just as effective interdisciplinary research for improving environmental quality can be organized and implemented successfully, we must try to organize an approach which will identify both data and associated models used and required for research in problems of environmental quality.

One can look at this problem as a situation analogous to artists and models. The acceptable portrayal of the human form is one of the most difficult of the artists' objectives and the one accomplishment to which so many artists aspire. The artist prefers to work with a model. One may think that an interdisciplinary artist is unheard of, but, then, how many artists are required to build a model?

The difficulty artists have with their models is not that of depicting the complex curves of the human form. The difficulty is in capturing on canvas and transferring to others the qualitative aspects of his model—the mood, the attitude, the sense of being. Only the rare artists can portray the total scene associated with his model. Likewise, it is extremely difficult for a lone economist to exact a model of environmental quality attributes from the complexity of the environment. However, one can simplify and develop working models with associated data which will contribute to more effective research and applications in quality of the environment efforts.

My efforts here are directed toward the enumeration of various models which may be useful in research for environmental quality improvement. There are several possible models for environmental quality research. The particular model chosen depends on the use intended for the results. Three categories of models and associated data, which are useful in dealing with various aspects of pollution are presented: (a) theoretical, (b) descriptive, and (c) analytical. Of course, all models involve certain aspects of theory, description, and analysis.

THEORETICAL MODELS

There are at least two theoretical models which are inherently philosophical and which are the bases for much disagreement with respect to the environment and to pollution control. These models are well described by Barnett and Morse [1, ch. 3] in their book, *Scarcity and Growth: The Economics of Natural Resource Availability*, as the scarcity model and the abundance model.

Scarcity Model

The scarcity model is the popular version of the Malthusian doctrine of absolutely limited resources for human sustenance. Even Malthus believed that the food supply would increase arithmetically. The constituents who promote this model base their predictions on the population growth rates. Sources of data for these models include any optimistic human demographic study properly combined with a pessimistic demographic study of a near-extinct species, such as the California Condor.

Abundance Model

The abundance model is more appropriately referred to by Barnett and Morse as the model of increasing relative scarcity. It is popularly described by economists as the Ricardian model. This model views our resources as unlimited in quantity but decreasing in quality. This situation, when accompanied by economic development and population growth, requires increasing inputs of capital and labor to the natural resources base for smaller outputs. The underlying premise is that natural resources are not homogeneous in nature but rather of various discrete units with respect to quality and quantity. The Ricardian increasing scarcity model has often been accepted by professionals, policymakers, and citizens with a bias toward increasing abundance, rather than increasing scarcity—especially during periods of rapid technological developments, high levels of capital investment, and high labor productivity. The basic data sources in these models include price-income data and physical production records.

The doctrine of increasing scarcity is deductive, viable and attractive to both preservationist and conservationist movements. The doctrine is also attractive because it is a part of the premise of Darwin's theory of biological evolution, as well as some social scientists, such as Malthus, Mill, and Ricardo. The increasing scarcity models lead scientists to infer that the correct solution for environmental degradation is the increase in social welfare through physical and administrative efficiencies. The solutions for natural resource problems are often those of direct government intervention with public power over public and private decisionmaking. Very often inadequate recognition, or concern, has been shown for economic efficiencies.

If, in fact, economic growth and welfare are the scarcity of natural resources model, then the moral, social, physical, biological, and economic implications of such a model will be different than if the increasing abundance model is true.

DESCRIPTIVE MODELS

There are a large series of variations of descriptive models adapted to environmental quality analyses. These descriptive models often serve as inputs for the analytical models.

Climatological Models

The climatological models for environmental quality research include inputs at both the micrometeorological and macrometeorological levels. The data include records of rainfall, temperature, runoff, humidity, wind, cloud cover, and other meteorological observations. These records are available on a current basis through the National Weather Service (N.O.A.A.), or historically from the National Weather Records Center in Asheville, N.C. The records are generally good for the major reporting stations but are strictly limited from the small volunteer observation stations. There are not many subsystem models relating these climatic and meteorologic data to pollution levels in the air or water with the exception of temperature inversions associated with areas such as Los Angeles and Denver.

Hydrologic Models

Hydrologic models are particularly useful with respect to water quality control. The hydrologic models include data on rainfall, runoff, streamflow, watershed yields, percolation, groundwater, and other data, both currently and historically. These data are available through the U. S. Geological Survey (U.S.D.I.) and the National Forest Service (U.S.D.A.). Relationships between streamflow and storage (for flood or drought) can be portrayed with mass curves and with statistical evidence from the network of gaging stations.

Atmospheric Models

Atmospheric models related to pollution control are extremely limited. Considerable research has been done, mostly on the upper atmosphere, but data for modeling atmospheric relationships to environmental quality do not seem to be readily available.

Land Use Models

Land use models are plentiful on a local planning scale. They are most often designed for specific purposes such as economic development, zoning for traffic and utilities control. Model land use plans which include environmental quality enhancement as an explicit objective are few. Most land use models are heavily oriented to existing institutional arrangements and to suggested "zones" of optimum uses based mainly on the location theories of Von Thunen, Weber, Hoover and others. Data for land use models are often from surveys of land forms, population densities, crop patterns, traffic counts and other descriptions. Land use models based on these inputs could be useful tools in interdisciplinary research for pollution control. The current land use models which do not provide environmental links of land, water and air are inadequate for the needs of the increasing population concentrations of urban areas. There is an increasing tendency for land use models to be designed specifically for large metropolitan areas on an independent resource basis (i.e., land, water, and air are treated independently of each other). The metropolitan planning organizations have large opportunities and responsibilities for modeling environmental quality. They have the opportunities through the availability of basic data and the responsibility to do so because of the dynamic, rapid cycling of metropolitan areas from zenith to decay.

Institutional Models

Institutional models related to environmental quality are often constrained from effective pollution control by the inflexibility of the institutional arrangements with respect to the allocation, transfer, utilization and preservation of resources. There are the inevitable conflicts between research results and implementations because of separation of powers and the existence of awkward (from a natural resource viewpoint) politically drawn data bases. At the present time, many states are providing leadership in modeling new institutional arrangements for pollution control. Much of this new leadership results from a combination of fears within the states that federal controls could prevail or that local governments cannot maintain environmental standards. Nevertheless, some innovative institutional models for pollution control are being developed.

Recent interests of states center around "Statewide Unified Programs for Environmental Protection." These models take many names from ecology commissions to environmental management boards.

Another innovative approach is the environmental quality institute which is designed for research, planning, coordination, and policy suggestions for maintaining environmental quality. The institutes are free of the enforcement onus and, therefore, have an opportunity for suggestive research and innovations at state and local levels.

Maryland has adopted the public utility concept in the creation of a statewide sanitary district as its model for pollution control. The sanitary district can acquire, design, construct and operate waste treatment and disposal facilities, fix rates and fees, borrow money and issue revenue bonds. This statewide authority could adopt the Genossenschaften model of the Ruhr Valley for regional waste treatment described by Kneese and Bower [11, pp. 232-254].

Additional institutional arrangements for environmental quality management include the usual punitive legislation, effluent (user) charges, and truth in pollution acts.

The river basin compact approach to handling problems of environmental quality seems to be an acceptable model for U. S. conditions. We have the Colorado River Compact and the Delaware River Basin Commission as models and as sources of information. These special purpose governments are a useful departure from the traditional vertically integrated and multipurpose governments from precinct to state house.

These institutional models for environmental management purposes are useful to the research scientist in understanding the reality of and, thus, the possibilities of producing effective research. Effective research is defined as that which is adopted, implemented or useful in achieving results. It is not appropriate in the time allowed to survey the landmark legislation or judicial acts which mold and constrain the basic approaches to environmental quality enhancement.

Management Models

Management models of environmental quality have been developed for water resources but are not generally used for air and land resources. Management models may range in complexity from the simplest watershed test plot to major basins, such as the Tennessee Valley. The major aspects of data and scientific methods in the management models involve the complex relationships among secular variations in resource cycling. This includes questions of eutrophication, drought and flood control, cultural cycles, and vegetative cycles (especially the development of steppes), climax forests, etc.

The models used in research for environmental quality, which have been described, fall largely in the realm of the physical and biological sciences. The models which economists are familiar with include those based on traditional economic base data. These are covered in a sketchy manner to provide an overall view of the complexity of models and subsystems with which we must deal in environmental problems.

Investment Models

The first economic type model in my list is the investment models. The investment models come in three basic forms or variations. The most encompassing investment type model is the traditional benefit-cost model—a tool useful in defining the degrees of economically justified pollution. The data for these models range from excellent to nonexistent. For example, the benefits and costs associated with power generation are sometimes well defined and evaluated while those from fish and wildlife are less developed, low confidence estimates. However, major efforts are being made by ecologists and biologists to provide the necessary evaluations of alternative actions with respect to fish and wildlife, specifically, and ecology, generally. The investment and institutional models should serve as a bridge between the economic, the biologic, the hydrologic and other models. The investment model requires valid inputs from most of the other models. The basic investment models are described by McKean [13], Eckstein [4], and others.

The second investment type model describes the influence of waste discharges on public investments, or vice versa. These models may also include income distribution aspects of public investments, as reported by Haveman [7]. Also, see Haveman and Krutilla [8].

The third basic form of the investment model is that produced mostly by agencies [6]. These models project the normative annual level(s) of investment needed to meet minimum and alternative standards for waste treatment (primarily water and solid wastes).

Population Models

The population models are integral to the problems of environmental quality. Population expectations are an input into most of the economic, institutional, management, ecologic, and investment models. The basic population models are provided by the U.S. Bureau of the Census. Many modifications to these models are made with respect to differing evaluations of effects and alternatives, such as those of Ehrlich and Ehrlich [5].

National Economy Models

The economic models useful in analyses of pollution are essentially data bases for projections and analyses of demands, prices and other factors. These models are discussed here in terms of the national economy and are defined as the income models, expenditure models, distribution models, and consumption models. Recently, Boulding [2] alluded to this type organization.

The income models provide data on Gross National Product, employment (unemployment), personal income, disposable income, income transfers, population and inflation rates.

The expenditures model provides data and insights on personal consumption, private domestic investment, exports (imports), balance of trade, and government purchases (for other goods and services, as well as national defense).

The distribution models provide data on wages and salaries, business and professional income, farm income, rental income, corporate profits, and interest.

The consumption models are divided into a number of sectors, depending on the uses intended, the geographic application, or the preferences of the user. The consumption of the productive capacity of the economy can be described in a 3-sector model as nondurables, durables, and services. However, an 11-sector model is more useful when disaggregated to food, clothing and shoes, gas and oil, other nondurables, furniture and household equipment, automobiles and parts, other durables; and, housing, household operations, transportation, and other services.

As one can observe from this shopping list, the level of the economy and the various mixes of the economy (with respect to income, expenditure patterns, distribution patterns and consumption patterns) greatly affect the attainment of environmental quality goals.

These descriptive models, or the sensitive parts thereof, for the hydrology, climate, weather, atmosphere, ecology, land use, management and institutions, investment, population and the national (or local) economy must be included in any complex environmental quality or resource use model, including the analytical models below.

ANALYTICAL MODELS

There are two basic analytical models, both of which depend on the inputs from the simpler models or subsystems described above. These two are the optimization models and the simulation models—both well known to economists from other applications.

Optimization Models

The optimization models (techniques) include linear programming, dynamic programming, queing theory and network programs (C.P.M. and P.E.R.T.). Standard algorithms for optimization of complex systems are not well developed for some types of practical applications. However, improvements are available to compete with such lower cost alternative methods as benefit-cost analysis. Optimization at subsystem levels has been acceptable, for example, for single purpose investment decisions. Optimization techniques sometimes give surprising results. The optimum pollutant concentration may increase with decreasing capacity or flow rates because of the increasing marginal cost of waste removal with the existing system. Although this is understood by economists, it is difficult to convince a public health official of the desirability of this.

Simulation Models

Simulation seems to be the preferred tool by simulation analysts for both design and management of complex environmental quality systems. Simulation presents the researcher with a physical function, combined with an economic effect, through a series of prototype systems with computer algorithms. Simulation can sequence a number of events. For example, a design prototype could sequence hydrologic events, economic events and associated alternatives for a system output dependent upon a large variation in magnitude, timing and sequence of all three series of events.

Additionally, once the sytem of pollution control is described physically in terms of desired relationships in the hydrologic and economic systems, then uncontrolled events may be specified in the simulation model. These uncontrolled events may include hydrologic events (from actual or synthesized streamflow data), meteorological events (from actual or synthesized weather data), and economic events to include historical data or projections. The economic events may be sequenced in terms of expected growth and development patterns, or as a probability distribution of states of the economy. Also, any random number generation technique for stochastic events or Markov chains of n^{th} order interdependencies may be introduced.

These analytical models are detailed in publications by Maass et al. [14], Hufschmidt and Fiering [10], Davis [3], and others.

Systems or analytical models (especially, if operated on river basin or appropriate political subdivision bases) are effective devices for research to improve planning, investment, and operating decisions. The accuracy and usefulness of these models are limited by the data inputs.

At the present time, data inputs for hydrology, climate, investment, the national economy, population, and institutional restraints are acceptable for planning investment and operating decisions. However, data for contaminant standards, weather, stream-reservoir or atmospheric contaminant loading capacities, land use, management, local economics, and particularly ecology, are not adequate for long-range decisions. Also, there are great needs for knowledge and understanding of the complex relationships among environmental quality standards, purposes, goals and conflicts. For example, a firm's water pollution problem can often be solved at the expense of air quality. Also, alternatives for achieving environmental quality are poorly identified and measured. For example, what are the alternatives to lake fishing in terms of stream fishing, not fishing, etc.?

One new approach which may be taken would be to allocate environmental resources on the basis of larger subsystems or purposes such as biological systems-economic systems-physical systems, rather than traditional purposes such as employment, recreation, low flow augmentation, and others.

SUMMARY

In an attempt to organize a variable and undefined area of data and models for effective research in pollution control, understandably, most of the detail one would expect in a discussion of a favorite model is missing. However, the main purpose was to bring to an economics group an indication of the nature of the models other disciplines are developing for research related to questions of environmental quality. These models, and, particularly, their data inputs, are required for effective systems research on environmental quality. A systems approach is mandatory for effective planning, design and operations and to avoid piecemeal, expensive or conflicting activities which do not enhance or maintain the total environment.

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