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PROCEEDINGS OF THE WORKSHOP ON NATIONAL/REGIONAL ENERGY-ENVIRONMENTAL MODELING CONCEPTS, MAY 30 - JUNE 1, 1979

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PROCEEDINGS OF THE WORKSHOP ON NATIONAL/REGIONAL
ENERGY-ENVIRONMENTAL MODELING CONCEPTS

Held in Reston, Virginia

May 30, 31 & June 1, 1979

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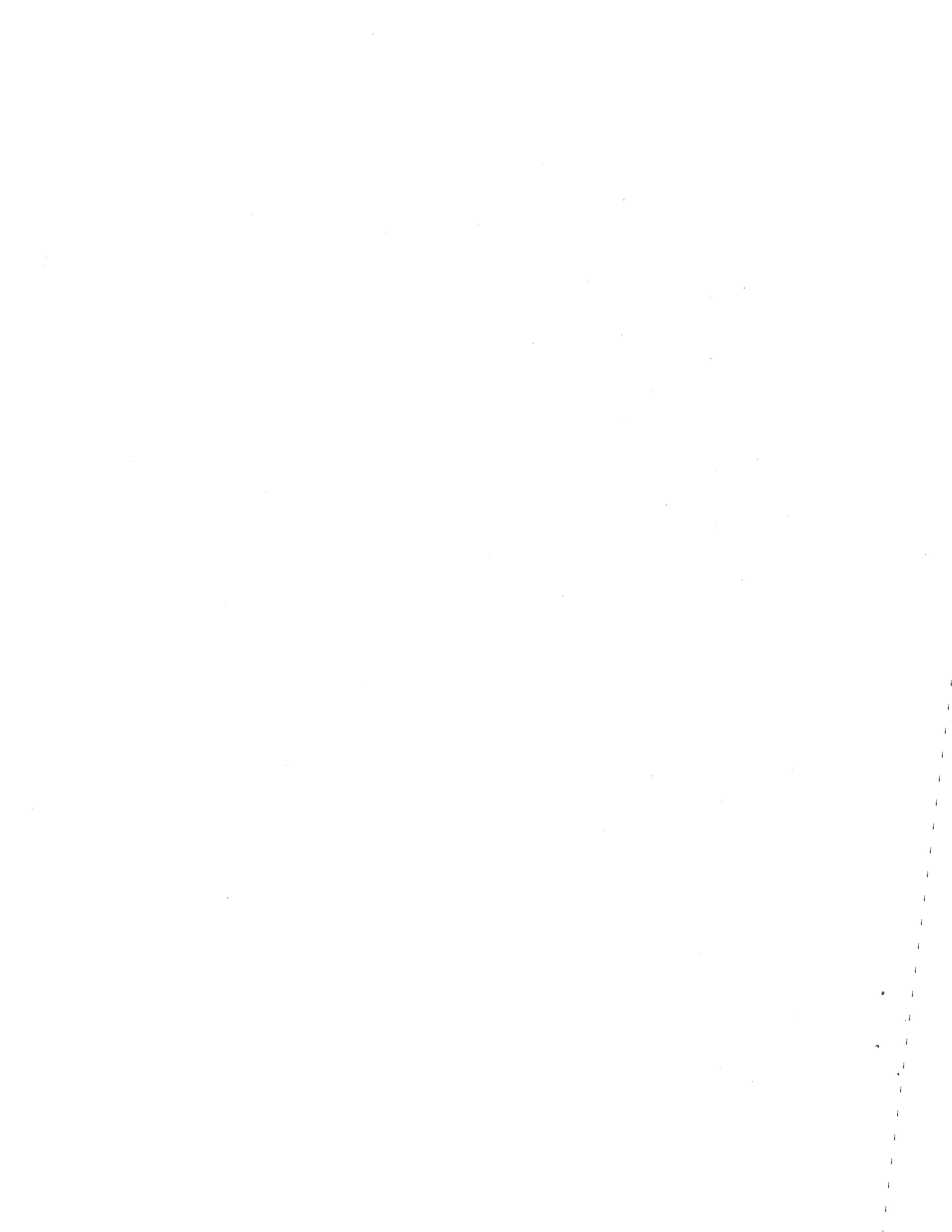
The authors wish to thank all the individuals who provided us with advice, insights and support associated with the organization of the workshop. In particular, we thank the following individuals who served on a steering committee: Professors David Wood of MIT and T.R. Lakshmanan of Boston University; Dr. John McLeod, Consultant; Dr. William Marcuse, Brookhaven National Laboratory; and Richard Bradley and Paul Cho from the Environmental Impacts and Regional Assessments Divisions, respectively of OTI/DOE. In addition, we wish also to thank the working group participants who reviewed the working group reports and provided useful comments and suggestions.

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PROCEEDINGS OF THE WORKSHOP ON NATIONAL/REGIONAL
ENERGY-ENVIRONMENTAL MODELING CONCEPTS

EXECUTIVE SUMMARY

The workshop brought together experts from various fields to identify approaches for integrating the top-down and bottom-up methodologies currently being used by DOE/OTI. Several major problems that would limit using such an approach in energy policy analysis described on the first day of the workshop, were discussed on subsequent days by three working groups. The conclusions and recommendations of each group are presented in order to address the overall theme of the workshop.

A need was expressed for both top-down and bottom-up approaches so that all interactions in energy-economic-environmental modeling systems could be adequately represented. For the short-term, recommendations were suggested for improving the current OTI models, but most of the comments were directed toward the development of a new methodology. It was recommended that a core set of related models be developed that are modular, dynamic and consistent: they would require an inter-industry accounting framework; inter-regional linkages; and adequate documentation. Further, it was suggested that an advisory group be formed to establish the appropriate methodological framework of the model system.

With regard to data used in any policy analysis model, it was recommended that OTI develop and maintain an integrated system of economic, environmental and energy accounts that is coordinated with the statistical agencies that collect the data. It was further suggested that an independent group be established to oversee energy data collection, coordination and verification. OTI can play a major role in ensuring that the data it needs for policy analysis models are collected and compiled in a suitable way.

The basic discussion regarding the use of models in policy analysis centered on the need for state and regional involvement in the assessment process. It was suggested that the state act as the basic geographic unit. State involvement was encouraged for use in the siting and disaggregation processes as well as in the interpretation and evaluation of the impacts. Further, there were several recommendations presented to improve the design of the assessment program. These covered the areas of energy and economic scenarios, cost of environmental standards, and the appropriate timeframe for conducting

the workshop. The topics of the subpanels were: measurement issues and approaches; structure of models; and application of models to policy analysis. The working group members were responsible collectively for developing a list of recommendations on their assigned topic during a day-long discussion period.

The last day was a plenary session in which the reports from each of the working groups were presented. An open discussion period followed each presentation and provided an opportunity for further elaboration and refinement of the specific issues and recommendations produced by the workshop participants.

The proceedings are organized into three major sections. The "Keynote Address" contains the presentation by Dr. Peter House. The section entitled "Perspectives on Modeling" includes a brief description of each of the seven presentations given during the opening session followed by a summary of the discussion period. Finally, three Working Group Reports are presented that contain the recommendations and conclusions prepared by each subpanel. An attempt is made to incorporate the working group findings into a final set of recommendations which appear in Appendix A.

Two additional appendices are included as general background information. Appendix B describes the relationships between national and regional models from an historic perspective. Appendix C is an introductory essay which discusses the connection between data quality, model complexity and the degree on uncertainty in the results.

KEYNOTE ADDRESS - Dr. Peter House

The terms "top-down" and "bottom-up" sound like something which would be banned in Boston. In this instance, the terms refer to different conceptual approaches to model development (although this too might be banned in some quarters). The beliefs and strategies of proponents of these approaches often make for interesting reading and have provided entertainment at several professional meetings. They also suggest information capabilities of different types that are needed in formulating national policy. It is latter subject which interest us now.

Top-down analysis suggests methodologies which attempt a more global perspective of the relationship between variables. Normally, the analyses produced are relatively holistic in nature, and attempt to investigate strategic questions of national policy. Data are collected at a relatively course grain (State or Federal region as opposed to city block), and relationships between the variables are represented by average coefficients rather than by specific activity levels. These models are used both for research and analysis purposes to test first-order consequences of various strategy alternatives and to look for unanticipated effects of various courses of action.

Bottom-up analysis normally means the integration of the results of a series of detailed analyses to produce a complete national or global picture. These individual analyses, in contrast to the above, are more detailed and represent more clearly the specific areas or portions of a problem. Such analyses are often used in assessments of national strategies where time and resources allow a more detailed survey. Often issues of a less analytical nature are introduced into these analyses. The data and relationships modeled in these studies are of fine grain and might, for example, contain spatial analyses locating impacts of various policies in a more precise fashion.

The debate that occurs when one tries to assess the relative merits of one of these approaches over the other rings hollow when it is taken out of the intellectual arena and finds its way into real life policy issues. It then become clearer—there is no simple-minded response to which of these approaches is "best." Obviously, it depends on a whole series of factors: the specific policy, time and resources available, where the decision is being made, and so forth. In the best of all possible worlds, however, one would hope that an agency would have both types of models available. The

results of a top-down analysis could be directly utilized by the family of models using a bottom-up methodology, and vice versa.

This capability would allow an agency to utilize the analysis produced by the more macro approach as a bounding condition of micro models. To some extent, this suggested technique solves the problem of too general and regionally insensitive results obtained from the top-down models, but does impose a tyranny of total value limits on the bottom-up segments. The latter is important since the essence of the bottom-up approach is that the totals are "discovered" by summing up the values obtained in the several detailed studies, and the aggregated totals may not equal the discovered totals.

A true bottom-up approach is likely to be less than totally useful to Federal policymakers if their use is meant to be repetitive and on a relatively short time demand. The organizational and administrative problems of continually exercising such a network would likely be impossible or at least a feat of impressive skill. Further, there is an inherent weakness in producing unbounded partial analyses of policies as each study area makes up its own mind as to the share of the total policy or impact it will have or cause. The so-called "chamber of commerce" effect often noted in areas such as geographic analyses where local bias creeps into the results and the integrated impacts when calculated are for greater (or less) than could realistically be anticipated.

For these reasons, I would suggest that the Workshop concentrate on the problem of mitigating the worst deficiencies of the top-down approach by enriching the macro analyses with more specific studies. For those who disagree with these suggestions, however, feel free to pursue alternative avenues.

Of particular interest are the answers to questions of the following sort:

- Can there conceptually be a successful integration of the top-down and bottom-up approach? If yes, what would each of these systems contain? How would they link?
- Institutionally, how would one house, care, and feed the system of models and analyses that the above design would portend? Where should it be housed, inside, outside the government or some combination? How does one go about running all or part of this system for

analysis? How does one decide what parts to run for what analysis?

- Administratively, what should such a system cost: to build, to run, and maintain? Should it be the captive of only one agency?
- Specifically, how does one go about demonstrating the validating of the results obtained from the system? How do you improve it?

These questions are hardly exhaustive and are meant only to provide a start for you in your individual task groups. The problem is very difficult and the implementation no doubt as difficult, but if it can be done and can be demonstrated to give superior answers to our increasingly complex policy issues, there is little doubt it will be used. You represent a collection of some of the better thinkers in these fields and know of the difficulties before you. Your presence here suggests that you have accepted the challenge.

PERSPECTIVES ON MODELING

The following perspectives on modeling were presented by seven participants representing a variety of economic, energy and environmental disciplines. The speakers were chosen to provide background and experience for the subsequent discussions of modeling approaches. Two of the presentations were given by OTI staff to provide background on OTI's modeling effort and policy concerns.

Roger Shull, Director, Environmental Impacts Division, Department of Energy

Roger Shull reviewed the DOE/OTI Policy Impact Assessment Program. The major programs of OTI involve national simulations as well as analyses of regional variations in environmental quality. He emphasized use of the SEAS model which is a "top-down" approach, with economics calculated using a 200-sector national input/output model. The results are disaggregated to the federal regions and states and to about 650 processes. Environmental impacts are calculated for the 650 processes at the state level and allocated to determine local impacts. One of the major problems, according to Shull, is that where ten years ago the problem was to evaluate policy questions quantitatively, there are now so many quantitative approaches that they themselves must be evaluated.

Summary of Discussion

A question was raised about which models have been validated and could be used as a nucleus for building a system of models in which decision-makers had confidence. It was stated that the purpose of a model is to prevent bad decisions, not to predict the "correct" answer in the future.

The discussion centered on whether there are any good regional models and where they are presently housed. A comment was made that OTI send their results from the SEAS model to the national laboratories for further regional analysis. The final discussion related to the economic modeling capabilities of the national laboratories. The problem of national/regional interface may not be related to the existing models but to the interface of the organizations.

Richard Ball, Environmental Impacts Division, Department of Energy

Richard Ball presented the SEAS model in more detail. The calculations start with national level policy variables and technology characterizations. Energy supply/demand balances are calculated regionally using the MEMMS (revised PIES) model. These balances are inputs into the SEAS input/output model (INFORUM), which generates activities and pollutants that are then disaggregated to determine the regional discharges. Finally, using estimates of the population at risk and the local ecology, environmental and health impacts are evaluated.

Summary of Discussion

There was a brief discussion of what variables are sensitive in policy analysis. It was pointed out that the inputs to models come from many levels. The level of geographic detail over time was identified as an important parameter.

Walter Isard, Cornell University

Walter Isard noted that a policy represents constraints on a model. These constraints are used as inputs to models which then can estimate the impacts. Isard summarized the modeling techniques that might be used in constructing a model useful for policy analysis. These techniques include: a) cost models for energy-using industries based on location theory. The capital requirements would feed into a b) multi-

regional input/output model with c) pollutant coefficients. This would produce the d) energy requirements by region and sector. By identifying the sources of energy supply one could build an e) energy transportation model(s). Finally, the f) local pollutants from the various energy supply facilities can be calculated. The theme of Isard's presentation was that many models are currently available (e.g. multi-regional input/output, econometric, linear programming, etc.) that can be linked together to solve the national/regional integration problems.

Summary of Discussion

Several problems with this approach were discussed. First, the nodal demand concept, i.e., concentrating demand in one place, may not be realistic for most energy transportation models. The transportation costs and modal splits will not be handled properly. Secondly, it was questioned whether this approach is predictive or only used for comparing alternatives. It was felt that the location theory models for industry were predictive and that I/O models were also predictive over a limited time horizon.

It was pointed out that this sort of "top down" approach was appropriate for all problems. General policy can be done by "top down" models but local impacts require some type of "bottom up" approach. A model of this size requires a large commitment for data acquisition and updating. Discussion centered on who could use the model and for what purpose.

Finally, it was noted that I/O models can help to show if a scenario is feasible in terms of resource availability and impacts. Further, these models can be used over a longer time frame if the coefficients are modified to reflect changes in technology.

Edward Quade, formerly of RAND Corporation

Edward Quade presented a historical view of modeling based on his earlier studies for the Department of Defense and RAND Corporation. He pointed out some of the pitfalls of using models for policy analysis. These included: defects in the model structure, implementation of the results, development of the models, data and information needs, and interpretation of the results.

Quade cautioned that modeling is only one aspect of policy analysis. Models do not always consider non-quantifiable factors such as equity, participation in decision making, and other social impact areas. Furthermore, the models are usually biased by the values of the modeler.

He recommended use of small, simple models that are linked together. As an example, Quade mentioned a San Diego pollution study conducted by RAND which uses 10-15 models that are linked together. These models are used to produce a matrix of impacts in relation to various policies.

Summary of Discussion

The discussion addressed the bias problem which some participants believed could be solved by using rival models and comparing the results. It was concluded that the assumptions used in constructing any model should be stated explicitly. Finally, the question was asked whether we need bigger and better models. It was felt that the modeling techniques are much further advanced than the available data so that data often become the limiting factor.

William Marcuse, Brookhaven National Laboratory

William Marcuse began by noting that no policy analysis models are predictive. They give a systematic structure for comparing technologies and policy alternatives. Marcuse provided a summary of the various modeling approaches. He discussed models under the following categories: aggregation and disaggregation, e.g., hierarchial, interdisciplinary, intertemporal; model selection, e.g., linkages, intertemporal considerations; and kinds of models, e.g., econometric, process, behavioral.

Finally, he described two hierarchial structures in which one can enter the model at any level. Marcuse believes that process models are useful in evaluating policy options. Most process models can look at current stock, processes and trends in order to forecast new energy sector coefficients. Institutional problems however are not handled well in either econometric or process models.

Summary of Discussion

The discussion centered on whether OTI was doing predictive or comparative assessments. It was stated that the models and analytical systems should not be used as predictors, but as comparative reference systems against which a set of scenarios is compared. Even though there was ample justification given for the scenario approach, there was some discussion as to whether that methodology is the best. Finally, it was noted that DOE needs generalized methods and techniques for addressing a wide range of policy questions.

Robert Wendling, Bureau of Economic Analysis, Department of Commerce

Robert Wendling described the "bottom up" modeling effort at the Bureau of Economic Analysis. This system termed the National-Regional Impact Evaluation System (NRIES) is designed to estimate the spatial distribution through time of impacts resulting from policy alternatives. The model may also be used for medium-range (5-10 years) forecasts of regional economic and demographic activity. While the model has no pollution parameters, pollution abatement expenditures are implicitly internalized and measured by the estimation procedure.

NRIES consists of 51 state econometric models integrated into a national framework. Because of the model's unique bottom-up structure, the overall level and regional distribution of economic activity in the Nation are simultaneously determined. There are several advantages claimed for the approach employed by NRIES. First, because one of its elements is an interregional model, NRIES can be used to analyze the regional or spatial distribution of policy impacts. Second, the system simultaneously determines the level of both national and regional activity. Third, by integrating regional and national models, the NRIES structure insures that the sum of regional activity is consistent with reasonable forecasts of national activity. Finally, NRIES is able to examine the effects of concurrent national and regional policy changes.

Summary of Discussion

The discussion revolved around specific features of the model such as how the cost of pollution control is incorporated and whether the system considers the sulfur content of coal or other fuels. The general question was raised about the appropriateness of econometric models when conditions were changing so rapidly. The model was characterized by some as merely an impact assessment model and not a forecasting or scenario evaluation model. Wendling gave examples of how NRIES can capture certain impacts which a typical "top down" (nationally controlled) model could not. It was questioned whether regional estimates are better than state and if potential state errors are cancelled out at the regional level. The reply was given that national totals are more accurate but that data and calculations are at the state level. Currently, the Energy Information Administration is attempting to couple this system with an energy demand forecast.

T. R. Lakshmanan, Boston University

T. R. Lakshmanan discussed classes of policy questions. He distinguished between short term policy issues which involve specific tactics, e.g., the gasoline crisis, and longer range strategic questions, e.g., the best technologies for R & D. Each class of policy question would probably require an appropriate set of models.

Lakshmanan then outlined an approach for integrating national and regional models. Since most large organizations similar to DOE typically have a decision making hierarchy, he proposed a multi-level, multi-objective system. The structure of this system included spatial, functional and inter-temporal components. The hierarchical organization is composed of vertical arrangements of subsystems where higher level units have some priority of action over the lower level ones. However, these higher and lower subsystems are interdependent and require information flow among them. He described the obvious problems of data and information flows between the various levels. Finally, he noted that model-building is usually a "top down" process in which one proceeds from a formal system to a conceptual model and then to an empirical model with quantitative relationships and simulations.

Summary of Discussion

There was discussion about the coordination among agencies concerning the use of models. The consensus was that there is little coordination and there are problems with documentation and consistency among models. Further, the documentation for data and model systems is usually lacking. About 25-30 percent of the total cost of any analysis or model development program is for documentation but often is not funded.

MODEL STRUCTURE:

WORKING GROUP REPORT (1)

T.R. Lakshmanan, Chairperson

Jayant Sathaye, Editor

Richard Ball

Robert Bolling

Richard Goettle

Curt Harris

Hubert Hinote

Walter Isard

John McLeod

George Treyz

MODEL STRUCTURE

Introduction

The model structure group, one of the three groups set up during the workshop, convened for roughly a day and a half with ten participants and several observers taking part in the discussions. In summarizing the discussions here, we have attempted to include all the varied but significant viewpoints expressed by participants in the group. As such, every viewpoint expressed does not necessarily represent a unanimous opinion, although the central theme of the discussion regarding long-term and short-term recommendations was generally agreed upon by the participants.

Model organization and emphasis are usually oriented along influence directions and are dictated by constraints placed on them. In economic-energy-environmental models (EEE), these constraints and influences are imposed both from the national and the local level. Hence any realistic model designed to embody all major behavioral phenomena relating national-regional-local policies and dynamics of economics and environmental activities must be organized with bi-directional constraints or influences. It was therefore the view of this group that interlinked models that capture this two-way informational flow be implemented both in the short and long term.

In this context, the feedback loops become very critical. The manner in which this feedback is communicated, whether by machine or by man, will also decide the accuracy, bias and speed with which policy questions will be analyzed. It was pointed out that the feedback loop, so common to economic interaction, often does not exist in environmental modeling where the obvious directional constraints operate from the top down. For example, an aquatic ecosystem model of food uptake would have only a weak feedback from the fish, algae and so forth. However, for EEE modeling a top down and bottom up approach is essential to adequately capture all the interactions.

Recommendations

There was a consensus in the group that a multi-level modeling system built around a unified national-regional accounting framework was the correct way to analyze energy-economy-environmental interactions. The group recognized that several integrated EEE models exist and are being used actively within the Department of Energy. Each model system embodies a

combination of several analytical techniques to answer specific types of policy questions appropriate to the agency functions. One of the important functions of the Office of Technology Impacts (OTI) within the Office of Assistant Secretary for Environment (ASEV) is to assess the economic and environmental impacts of energy-economy projections.

In the context of policy concerns and policy analysis responsibilities of ASEV, the working group addressed improvements called for in existing analytical and information techniques. Separate improvements were suggested for short-term and long-term modeling efforts. The short-term recommendations generally suggest changes in the current Strategic Environmental Assessment System (SEAS) methodology and in its linkages with other models. The long-term improvements call for a new modular methodology with an integrated accounting system.

Long-Term Recommendations

Recognizing that modelers have had several years of experience in dealing with energy-environment-economic models employing different analytical techniques, the working groups recommended the following:

- Advisory Group

An advisory group of expert individuals be established to further investigate and suggest an appropriate methodological framework in which to analyze a broad set of policy questions. The group would be responsible for designing a core configuration of models and the information system needed to make these models practical. Earlier in the discussion it was apparent to the group that it would not be able to decide on the exact type of long-term model in the short span of the workshop and because of an incomplete understanding of OTI functions and responsibilities. However, it was clear that it would be relatively easy to delineate the essential attributes such a long-term model system should have.

- Modular

It was recommended that a core set of relatively simple analytical and informational systems be established in contrast to a single complex model. The system should be such that modules for

analyzing different impacts could be detached or attached with relative ease. The system would be modular in its choice of sectors, geographic regions, and impact areas.

- Consistency and Accounting Framework

Consistency among different models and accounting frameworks was deemed essential in providing reliable comparisons of different energy projections. One way to insure such a consistency would be to base the core set of models on an interindustry accounting framework with built-in mechanisms for aggregating or disaggregating the sectoral and geographic breakdown. Some of the advantages and disadvantages of the Multi-Regional Input-Output (MRIO) approach were discussed in this context. The accounting framework provided by MRIO was deemed highly desirable although the specific models and their uses appeared inadequate or questionable.

The set of models currently in use have certain built-in interdependencies between energy, the economy and the environment. None of the models appear to have consistent linkages between these three areas. The recommended core set of models would need to be planned carefully and reviewed to provide consistent and comprehensive linkages at the sectoral and geographic level of detail. Furthermore, the core models would undoubtedly include elements using different analytical techniques representing various approaches. It was felt that a proper combination of these techniques would significantly improve the analytical range of the core system. Four approaches were mentioned in this context: econometric models, process models, input-output models, and location theory models. Econometric analysis was deemed suitable for analysis where existing economic relationships were likely to hold. The technique may not be suitable for long-term analysis unless augmented by models of technological choice. For long-term analysis, it is essential that the parameters that form the basis for such an analysis be stable and that the relationships hold for the future or at least be predictable. For example, in the MRIO framework the trade coefficients are very unstable and may not hold for the future, whereas the technical coefficients are comparatively stable and can be updated. Location theory

was advocated as one of the techniques that would be used to avoid the problems of predicting trade flows as well as to serve as the major basis for the core model.

- Dynamic

The planning and review of the core model system ought to be a continual process where both the modeling techniques and data bases can be updated. This may require changes in technical and location coefficients as well as in geographic and sectoral detail. Further, the sequence of disaggregation--whether to break down into geographic detail first and then analyze the sectoral detail or do the sectoral detail first and then disaggregate by geographic regions--merits additional research.

- Regional Interaction

The core set of models could provide an effective means of communication among modelers in different regions or among modelers specializing in different sectors of the economy and the environment. The organizational and management requirement inherent in such a system of models were also recognized as a non-trivial problem. For up-to-date and reliable information, it was felt necessary that regional entities be involved in such a system. This would permit regional entities to communicate through computerized models or through other organizational structures. The choice of such entities in each region is important to soliciting an unbiased and quick response and to avoid the so-called Chamber of Commerce effect which allegedly plagued the Office of Business Economics and Economic Research Service (OBERS) forecast.

Technology sets for production and consumption by each region are one of the critical items in formulating a core set of models. The regional definition at which the set of models would form a consistent accounting framework and have such technology sets was disputed although the state boundaries were advocated as the appropriate level. Other regions mentioned included the Bureau of Economic Analysis (BEA) areas, counties and federal regions.

- Documentation

Lack of adequate up-to-date documentation was pointed out as one of the key deficiencies in understanding the various large modeling efforts being conducted in DOE. Recognizing that a major part of the effort would go into documenting the core set of models, it was recommended that a substantial effort be put into clearly identifying the assumptions, data bases and the linkages.

- Implementation

One way of implementing such a long-term set of models was outlined during the discussion. It consists of several steps which were generally agreed upon:

- (1) Provide a natural language description of the model including all the constraints and influences existing in the system being modeled.
- (2) Document the description and have it reviewed by experts both internal and external to DOE.
- (3) Determine the variables and parameters necessary to simulate the system.
- (4) Develop a flow chart delineating all the linkages and functional processes.
- (5) Outline the data requirements by sector, geographic region and impact area. Collect data and estimate the parameters.
- (6) Write a program for a relatively simple aggregated model.
- (7) Check with experts and the client to ensure that aggregations do not over-simplify the model.
- (8) Perform sensitivity tests on the model to indicate where data needs to be refined or the model could be modified.
- (9) Plan simulation experiments to examine the policy questions of interest to the client.
- (10) Analyze results and recommend reformulation of the model.

Some of the steps outlined were questioned in light of real life experience with EEE modeling. The results provided by these models are difficult to check against any criteria or guideline established to evaluate them. Also, an aggregated rough cut model has to be credible to begin with, otherwise the policy analyst is likely to have little or no faith in it.

Short-Term Recommendations

Short-term recommendations focused primarily on the existing SEAS modeling capacity within OTI. The SEAS model was generally described to the workshop participants, and several areas where deficiencies are apparent were brought out. The SEAS model as operated by OTI used the Interindustry Forecasting at the University of Maryland (INFORUM) input-output model as the major driver for estimating economic and environmental impacts (residuals, emissions, etc.). It is also coupled with the energy demand/supply projections made by the Energy Information Administration (EIA) using the Data Resources Incorporated (DRI) and Midterm Energy Forecasting System (MEFS) systems. The differences between MEFS and SEAS are the first source of inconsistency in the modeling capability.

Within the SEAS model, several inconsistencies were noted. The siting and population demand models are not linked, nor is there any linkage between energy industry and population location models. County industry location does not have any relation to energy demand and industry does not respond to changes in energy prices; the model lacks the flexibility to answer different types of policy questions.

Questions were raised about the necessity of the large 650 sector process detail in SEAS models considering that it is based on a roughly 200-sector INFORUM national input-output table and 29 sector OBERS breakdown. It was pointed out that the large number of sectors in an input-output model reduces the error in assuming national technical coefficients at the regional level.

It was generally agreed that SEAS has the requisite components of a desirable EEE structure for conducting a top-down impact analysis. However, there are some major areas that need to be addressed.

- Base year data needs to be improved at both national and regional levels.
- Accounting framework needs to be improved in the area of energy-economy interactions.

The top-down SEAS approach needs to be supplemented by a bottom-up approach. One way to achieve this would be to follow the existing system, letting the national laboratories respond to SEAS results based on their analysis at individual federal region level.

Summary

The model structure group concluded that top-down and bottom-up approaches are both essential to represent adequately all the interactions in energy-economic-environmental modeling. The group also recommended establishing an advisory group of expert individuals to investigate an appropriate framework for long-term OTI modeling activities. Attributes essential for a long-term core set of models were explored and delineated during the discussion. Short-term recommendations suggested improvements in accounting framework and in the basic year data bases of SEAS.

MEASUREMENT ISSUES AND APPROACHES:

WORKING GROUP REPORT (2)

David Wood, Chairperson
Henry Ruderman, Editor
David Bjornstad
David Leinweber
Victor Niemeyer
Frank Osterhoudt
David Sandoval
Tom Woteki

MEASUREMENT ISSUES AND APPROACHES

Introduction

Development and application of formal models in analysis of the environmental and socioeconomic implications of alternative energy policies is ultimately restricted by our ability to obtain implementing data through measurements on the underlying reality being modeled and analyzed.

The purpose of the Measurement Issues Working Group was to review the current status of measurement systems providing data for policy research and modeling in this area, and to recommend actions to aid the further development of these systems, as well as to improve their use. The recommendations fall into the two areas of (1) data systems and sources; and (2) procedure.

The analysis avoided discussions of particular modeling approaches and methodologies, although it was recognized that to some extent, modeling approach may determine data needs. The discussion also tended to focus upon comprehensive and continuing measurement systems as contrasted with special purpose efforts intended for particular, perhaps narrow, applications.

As an aid to the analysis, a paradigm of the analysis problem facing OTI was constructed that was employed to identify key measurement issues. The paradigm is as follows. OTI is responsible for analyzing the environmental and corresponding socioeconomic effects of specified energy policies. These analyses may range from impact assessments for a particular technology (residential applications of photovoltaic-based technologies) to general assessments of a complex national energy policy. Regardless of scope, these assessments are basically differential in nature, involving a projection of how the socioeconomic-environmental system will change due to the particular initiative being considered. The analysis problem is, therefore, twofold: (1) to understand and project the relevant system performance at the level of detail required by the analysis without the policy initiative; and (2) to interpret and analyze the implications of the policy initiative at the necessary level of detail, and to aggregate to levels appropriate for calculating and interpreting the differential effects.

The great difficulty in following this approach is that the detail of the socioeconomic and energy production, conversion and consumption measurement systems does not correspond to that required for the environmental impact analysis so that: (1) it is not possible to produce the reference case at the necessary level of detail; and (2) real data are not available to analyze and

model the detailed interactions that produce the differential effects one seeks to calculate. It should be noted that lack of detail goes beyond geographic classification. Perhaps of equal importance are activity classifications, process detail, fuel types and quality.

The essential point is that, as so many modelers lament, the data simply do not currently exist to close the loop in the analysis process described above. The working group makes this fact its point of departure and attempts to develop recommendations to improve this situation, cognizant of both the importance of the problem and the limits on resources and possibilities for expanding present measurement systems. An introductory essay is presented in Appendix C which discusses the relationship between data quality, model complexity and the degree of uncertainty in the results.

Data Systems and Sources Recommendations

- OTI must attach a higher priority to developing, maintaining and extending an integrated system of socioeconomic, energy and environmental effects accounts.
- OTI must interact more effectively with EIA and other statistical agencies to ensure sufficiently detailed energy production, conversion, transportation, and consumption data are available for use in its assessment models.

One of the problems in analyzing the socioeconomic and environmental impacts of energy policy initiatives is the lack of connectivity between the separate measurement and accounting systems that provide the basic data for modeling and analysis. Most disturbing is the fact that survey systems for acquiring energy production and consumption data are unrelated to those used in acquiring environmental effects data. The current inability to make these data systems congruent greatly complicates the modeling and analysis process.

The working group recommends that OTI work closely with EIA in setting up a system of national and regional energy accounts that would be consistent with the accounting system used for economic data. One of the important tasks is to define the categories and coverages of energy production and consumption data required for the energy policy analysis that OTI conducts. Specifically, the areas of concern are the industrial sector, location, fuel type, end use, and quality, e.g., temperature, of the energy.

Furthermore, OTI should assist EIA in formulating special studies designed to provide the more detailed data needed for modeling specific locations or technologies.

- OTI should acquire detailed environmental and technology characterization data for statistically representative geographic units, processes, end uses, fuel type, and quality, e.g., temperature. In general, increased use of statistical sampling to augment census survey data is recommended.

Although in principal, data are available at the level of detail needed for most impact analysis, practical constraints--time, money, resources--limit the amount of data that can be collected by survey techniques. The problem becomes more difficult as one goes from economic to energy to environmental data because the dimensions of the data increase. Moreover, as the amount of information requested in a survey increases, the quality of response may actually decrease because of the large reporting burden on the respondent. As a result, the data available to the modeler are not sufficiently detailed to be useful in analyzing impacts at the level required for policy analysis.

OTI should complement its SEAS program with highly specialized individual regional studies. For this purpose, a range of representative regions, technologies, processes, end uses, etc., should be selected. Adopting this practice would permit the gathering of specialized environmental and related data at moderate cost, thus facilitating in-depth analysis that could be generalized to similar regions. Such data may be available through EPA. OTI should coordinate with EPA in the collection and compilation of environmental data needed for detailed impact analysis. It should be emphasized that by using statistical sampling techniques for selecting the representative units it is possible to combine the sample and survey data and thus generalize the results obtained from the specialized studies.

An in-depth data collection effort of limited geographic scope would permit the tailoring of analyses in light of the individual issues and technology characteristics. It would relieve OTI of the need to collect data for every variable in a nationally consistent format and would permit more detailed examination of smaller issue areas. This contrasts with the current practice based on the top-down accounting methods, and would restore a balance between national and regional issues to the OTI analytical program.

- Statistical estimates of the uncertainties in the environmental and economic effects must be included both in the data used in calculating the parameters of the assessment models and in presenting model-based results.

The numerical results from models used in setting policy action are presented without any indication of the reliability of the results. Without knowing how accurate these numerical values are, the analyst cannot tell whether the differences he obtains are statistically significant. This difficulty arises because the accuracy of the data used in the model is often not known, or if it is, the models are so complex that the uncertainties in data are not easily translated into uncertainties in results. The working group realizes that some uncertainties such as those due to model structure are not quantifiable because of a lack of complete theoretical understanding of the phenomena being modeled.

Quantification of the uncertainties associated with modeling and analysis should ardently be pursued using actual measurement statistics, results of validation studies, or ad hoc parameterization (in order of preference). An important prerequisite for this is that the statistical uncertainties associated with the data used in the model be presented along with the data.

The uncertainties in the final results will often yield policy conclusions of the form: "within the limits of the analysis there is no discernible preference between these alternatives." When a clear and statistically significant reason for choosing a particular alternative emerges, the conclusion is far stronger when it emerges from a source credible enough to be able to say "I don't know" to impossible questions. It is unreasonable to always expect models to provide all the answers. Explicit recognition of this fact will serve to reinforce the contributions that modeling techniques and modelers can make to the solution of the policy problems.

Procedural Recommendations

- Current and prospective programs for acquisition of socioeconomic, energy and environmental effects data do not support comprehensive modeling systems. New modeling efforts should tend toward simpler models congruent with real measurements and should not rely on "synthetic" data.

The models that OTI currently uses for policy analysis are quite complex with a high degree of regional and sectoral disaggregation. The quality of the currently available data and of the data that might be available in the foreseeable future is not adequate for so detailed a model. These models are inefficient in the sense that the effort that has gone into achieving that level of detail, for example, into generating "synthetic" data, could more effectively be applied to acquiring fewer but better quality data for a simpler model. Many of the results of these models are based on the presumed detail in the data, which on closer inspection, is not really there.

The relationships between data quality and model complexity as discussed in Appendix C suggest two complimentary strategies that OTI might use to enhance its analytic capability. One is to forego any additional increase in SEAS model complexity, e.g., more sectors or more disaggregation procedures, in favor of efforts to achieve improvements in data quality. This is strongly advised in light of the analysis of complexity versus data quality. There are a number of data collection efforts under way within EIA, and OTI should consider making use of these resources. The second recommended strategy is that new modeling endeavors should be structured along the lines outlined by Ed Quade in his presentation, i.e., a family of small, simple models, each addressing one aspect of the problem, which can be used to form an impacts matrix with alternative policies on one axis and impacted areas (air quality, water quality, socioeconomic impacts, etc.) on the other. Simple models are easier to understand, quicker and cheaper to run, easier to develop and validate, and their uncertainties are easier to quantify. Simpler models also have less institutional momentum. They are thus far less likely to be applied (or inappropriately modified to apply) in areas to which they are essentially blind. The comprehensively large, highly competitive models are not justified by the data inaccuracies that are inherent in a field as uncertain as energy and environmental planning.

- OTI and EIA should sponsor an Energy Statistics Committee at the National Academy of Sciences or other independent body for continuing research, assessment and evaluation, and consulting on the development of energy statistical programs.

At present there is no independent body that oversees the collection, compilation and use of energy data. EIA has a group that does model validation in addition to the groups that validate energy information. There is also an ad hoc committee sponsored by the American Statistical Association which advises EIA on the use of models and survey methods. OTI's policy analysis models, however, are not adequately reviewed for the consistency and accuracy of the data used, which the working group believes contributes to a lack of confidence in their results by the modeling community, the policy analysts, and the public in general.

The working group recommends that OTI and EIA sponsor the formation of an Energy Statistics Committee at the National Academy of Science (NAS), the American Statistical Association or other suitable organization for the purpose of continuing research, assessment and evaluation, and consultation on the development of energy statistical programs. This permanent committee would continue the efforts begun by the NAS ad hoc Committee on Energy Consumption Data and other groups and would provide an organizational means for review and evaluation of current and proposed programs. This committee should consist not only of statisticians and others familiar with data collection techniques, but also of modelers and other users of energy data. Having such an independent overview group will induce more confidence in the data going into models and the results coming out.

- Independent model and data validation and verification must be emphasized if energy-environmental policy research and analyses are to be credible to peers, policy analysts and those affected by model-based policy decisions.

Modeling for energy and environmental policy analysis has not yet reached the stage where it can be considered a discipline. Models, the data used by them, and their results are not usually described in the open literature in enough detail to assess their validity.

The working group recommends validating all models used in support of policy research. The goal of validation is to give both the modelers and the users information about how models can be used most effectively and how much confidence can be put in the results.

Validation of models used for prediction should include a test forecast of data that is known but not used in estimating the model. The test forecast should be performed using both estimated and actual values of

exogenous inputs to distinguish errors due to difficulty in predicting the values of these inputs from errors due to model specification.

A second form of validity test should examine the model's structure to ascertain whether the model's behavior is consistent with the theoretical beliefs of its developers. A third form of validation examines the content of the model to check whether it contains the features necessary for the type of analysis for which it was intended. These types of validations check for the possibility of nonsense results and determine which issues the model can or cannot be used to examine.

EPRI has initiated two mechanisms for model validation, the Energy Modeling Forum and MIT's Model Assessment Laboratory. In the Energy Modeling Forum, different models are run over the same scenarios to provide a basis for discussion and comparison. Not only is this activity very helpful to the modelers, but participation increases the model's exposure and can increase its credibility. In the Model Assessment Laboratory, models are examined independently, but with the cooperation of the model developers. OTI should take advantage of these approaches to model validation.

The working group notes that validation, participation in energy modeling forms, independent model assessment, and sound model development practice all require good model documentation.

Summary

The working group on measurement issues examined the relationships between the data and the economic-energy-environmental models that are used for policy analysis. Since policy decisions can have their most critical impacts on a small part of the country or a single economic sector, it is often necessary to model impacts at this level. The quantity and quality of the available data, however, severely restrict the comprehensiveness of such a model. For use in a model, demographic, economic, energy and environmental data must be compiled on a consistent basis. Furthermore, survey data must be supplemented by statistical sampling to acquire the specific information needed for in-depth impact studies. OTI can play a major role in ensuring that the data it needs for policy analysis models are collected and compiled in a suitable way by establishing a formal interface between the modelers and the statistical agencies that collect the data.

A second consideration of the working group was improving the use of data so that the results of models could be made more credible. Although it is generally realized that uncertainties in the data lead to uncertainties in the results, they are usually not quantified in presenting the results to the policy analyst. Moreover, given the quality of the data, there is a point at which making the model more complex will give less accurate results. These considerations must be kept in mind when formulating policy models. The working group noted that the credibility of results would be enhanced if an independent group were to oversee energy data collection and if both models and data were independently validated.

USE OF MODELS FOR POLICY ANALYSIS:

WORKING GROUP REPORT (3)

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USE OF MODELS FOR POLICY ANALYSIS

Introduction

The framework within which a model or family of models is applied, and the relationship of this framework to the decision making process, are major determinants of the successful use of a model for policy analysis. The charter of the working group was to review the application of models for environmental policy analysts and recommend improvements for use of these numerical models. The group focused on the question: "How should models be used for OTI environmental policy analysis?" It should be noted that this framework excluded discussion of the structure of, or linkage between the models being used and of the sources, availability and quality of the data supporting those models. These latter topics were to be addressed by the other working groups. Detailed information on EV and OTI operating policies and structure were not available for review during the working group meeting. Therefore, the recommendations listed below do not always imply a corresponding known deficiency in OTI policies.

The discussion of specific recommendations centered on three topic areas. These were: regional involvement in the assessment process, design of the assessment programs, and the relationship between the modeler and the user (decision-maker). Of these, the first (increase regional involvement in assessments) was felt to be by far the most important. The following paragraphs present the discussions and recommendations of the working group in each of these areas.

Regional Involvement in Assessment Process

It was agreed by the working group participants that by far the most important recommendation that could be made to improve the accuracy, acceptability, and credibility of OTI model assessments was to substantially increase regional involvement in the assessment process. The specific recommendations listed below represent a series of implementation strategies for this general principle. It was further agreed that the state should be the basic sub-federal unit, or region, for implementing this involvement. The

state was selected as the basic unit since it was felt that implementation of federal energy policy will be dependent upon the state concurrence and support. More specifically, OTI assessments will benefit because:

- 1) The basic sub-federal political boundary is the state. States have appropriate institutions with regulatory and planning responsibility, e.g., Energy Departments and Public Utility Commissions;
- 2) Many decisions critical to energy futures are made at the state level, e.g., power plant siting;
- 3) The states can define and enact energy policies of their own; and
- 4) The states can act as a focal point for the collection, dissemination and analysis of local energy, demographic and environmental data.

The discussion on sub-federal units was directed toward identifying actors and institutions that should be considered. It was unanimously agreed that the computational assessment of pollutant transport and impacts may be appropriately conducted on other geographic scales. Long range SO₂ impacts, for example, may be analyzed at a regional level, while data input, state and local policies and impact interpretation could be provided by actors from each state within the region.

This set of recommendations represents the working groups effort to directly address top-down/bottom-up integration. It was felt that an appropriate integrating principle is the coupled concept of constraints and goals. Federal policies, goals and energy disaggregations (pie splitting) constrain state options. State policies, actions and goals restrict the opportunities available to DOE to fulfill federal scenario goals. Thus, the design and operation of a modeling system should allow (as a minimum) for both the transmission of, and consideration of goals and constraints between state and federal levels. The resulting format can serve as a basis for interactive communication between federal and state actors. Consistent with the concept of constraints is a hierarchical system of environmental impact assessment. Detailed analyses could be conducted by a regional entity (as is done by the national laboratories) based on "control totals" obtained from a DOE national assessment.

Two pathways were identified for infusing regional involvement into the OTI environmental assessments. The first of these is preassessment data inputs. State, local and private sector energy development plans, energy siting policies, and energy goals can both direct and constrain the implementation of federal initiatives. These data are now compiled at the state level and can be incorporated into OTI data bases as bottom-up constraints for industry, end use fuel, and utility disaggregation into regional, state, and sub-state areas. The second pathway is the development of an interactive hierarchical system for the cooperative conduct of the environmental assessment of an energy policy. In general, the use of the second pathway was recommended only for long period assessment and not for the quick turnaround studies, e.g., 1 to 2 week study duration. The first pathway is applicable for studies allotted either amount of time. The following specific recommendations are provided for the enactment of improved regional involvement in OTI assessments.

- Incorporate State-Level Inputs into OTI Siting and Disaggregation Systems.

Existing data bases, e.g., SEAS, used for disaggregation or siting energy and industrial activities should include state and local siting and fuel mix priorities, state energy development plans, goals and constraints, or regulations which could influence the future distribution of energy use. Individual states would be responsible for development and periodic update of this input either directly to OTI or through appropriate national laboratories. Format and spatial level of detail (state, AQCR, ASA, county, etc.) would be specified by OTI to insure compatibility with existing data bases and disaggregation schemes. The purpose of this expanded state data base detail is to modify federal energy disaggregations in order to reflect state and regional trends and policies, and identify possible impacts of state-level policies on federal scenario options. Implementation mechanisms for this recommendation include: data base modification, determination of state level points of contact, establishment of a data transmission and review process, and establishment of a data update and modification mechanism.

- Develop a common energy accounting system.

Establish, in cooperation with state agencies, a common structure for describing and accounting for energy flows in each regional or state energy system, including fairly detailed demographic and end use descriptors. The adoption of such a system by all state-level participants would substantially enhance the feasibility of the previous recommendation, and will establish a certain measure of consistency for interactive participation between state and federal levels for the conduct of environmental assessments of alternate energy policies. An inherent element of this recommendation is the development at the state level of a common historical set of energy data.

- Develop a taxonomy of environmental impacts.

Some environmental analyses are properly addressed as spatial aggregates at a national level, while others are best addressed at a multi-state regional level, e.g., acid rain or SO₂ in the northeast. Similarly, some studies require long-term assessments, e.g., life cycle analyses, while others can address only single year, e.g., impact of a revised environmental residual emission regulation on energy development. To the knowledge of the working group, the relationship between the nature of an environmental impact and the scales (spatial and temporal) for its assessment has not been made explicit. It is therefore recommended that a taxonomy of environmental impacts and the spatial and temporal scales best suited for their assessments be constructed. The adaptation of such a system would then direct the specific types of models and level of their application to respond to a policy related question. Some discussion was directed toward completion of such a matrix. However, time constraints of the workshop prevented substantive development. It is recommended that OTI undertake a cooperative program with regional representatives for the development of a taxonomic matrix and for its integration into the assessment process.

- Establish a hierarchical assessment methodology

This recommendation involves both structural and procedural components. Consistent with the impact taxonomy, OTI would directly calculate (using SEAS or other appropriate models) only those impacts best addressed at a national level. Resulting siting patterns and total activity levels would be used by regional laboratory and/or the individual states as drivers and as control totals for the socioeconomic and environmental impact assessment at the state or other level. Models to be used in this second portion of the hierarchy would concentrate on spatial distribution and ambient quality (bottom-up) models. Interface between the two levels of the hierarchy would be provided by the national and regional outputs and by state-level inputs to the siting process. Inherent elements of this recommendation are that OTI undertake a coordinated program with regional and state personnel to develop consistent, compatible state and sub-state energy-environment models, and that the assessment process represent an interactive iterative process. It is envisioned that this hierarchical approach would apply only for long-term assessment programs.

Design of Assessment Program

Environmental assessments conducted by OTI are now constrained to use only scenarios (national energy supply and economic scenarios) supplied by others. Current scenarios are designed to examine the effects of perturbations in GNP, world oil prices, population level and the like. While the resulting environmental assessments are useful, their true significance cannot be determined until the plausible range of energy-related environmental impacts has been determined. Such determination is dependent upon the generation and evaluation of scenarios specifically designed to explore variations in environmentally important parameters. What energy supply mix for the year 2000 generates the least environmental damage? Which mix generates the greatest environmental insult? What is the likelihood that either will be approached? What is the dollar and/or environmental cost of marginal changes in the future energy mix of a given scenario? Addressing questions such as these will provide a framework within which to evaluate the relative significance of the environmental implications of any specific scenario. Two specific recommendations were made. These are:

- Develop environmentally significant energy and economic scenarios.

Assessment of the environmental impacts of an energy policy requires the analysis of several scenarios based on that policy which were specifically constrained to address the range of resulting possible environmental impacts. As a first step, it is recommended that the development of environmentally significant alternative energy and economic scenarios be pursued. This will require that assumptions and goals are identified and incorporated into the scenario structure before PIES or other models are used to generate economic and total energy demand forecasts. Only in this manner can the environmental assessments conducted within OTI be consistent with basic scenario assumptions.

- Estimate the energy cost of environmental standards.

Techniques and measures are available, e.g., shadow prices, to estimate total and marginal costs of environmental standards and policies. These functions, placed in terms of energy cost, will provide a rational basis for the evaluation of beneficial changes in either present or proposed standards. It is therefore recommended that OTI initiate a program to estimate explicitly the energy cost of environmental policies and that the resulting cost figures be incorporated into DOE decision-making process.

Assessments were divided into long-term assessment and short-term assessments. It is recommended that, rather than separate these categories along fixed time spans, e.g., short-term is less than 5 years, short-term and long-term assessments should be differentiated by the nature of the environmental questions being addressed. With this type of differentiation, the need for a short or long timeframe study will also identify the types of models needed and the spatial levels at which they should be applied. It is suggested that:

- Short-term studies be used to address specific tactical questions.

Generally, short-term assessments are suited for emission related questions rather than environmental impact or ambient quality questions. The question, "What is the effect of delaying new auto emission standards for two years?" can adequately be addressed at the level of increased residuals over a fixed time period (two years).

Ecosystem and ambient quality impacts need not necessarily be addressed. Similarly, short-term assessments are suited for standards compliance issues, where the question at hand is how existing energy related emissions compare to some standard and to operational questions as opposed to those involving major capital investments. Short-term studies are appropriate for high spatial aggregation (federal region or nation), are often "quick response" studies, and should be evaluated in a top-down assessment mode. They are normally addressed in terms of residuals, and not the impacts of those residuals, and do not tend to require detailed regional or state input or interaction (bottom-up input).

- Long-term assessments: Impact assessment period should cover entire period of duration of impact.

The assessment period appropriate for consideration in a long-term environmental assessment should be based on the full life cycle of a major energy facility (often, 50 years), the Research Development, Demonstration and Commercialization for emerging technologies included in a scenario, and the duration of the environmental impact (the direct impact plus system recovery time). Thus major impacts on a forest ecosystem may require consideration of a hundred year timeframe in order to capture the full impact being assessed. The environmental modeling techniques used for long-term studies must be oriented toward the receptor systems (ambient quality modeling, human health or populations at risk modeling, and spatial and temporal distribution of residuals assessments) rather than toward source systems, e.g., emissions studies.

These techniques are "bottom up" modeling approaches which should be applied at regional, state and sub-state levels and will thus require coordinated analysis throughout the country. Therefore, long timeframe studies require longer study times than will involve some iterative interaction between federal and state or regional representatives, tend to be strategic rather than tactical, and will focus on the environmental/health impacts of the residuals rather than emission rates themselves.

It is recognized that impact forecasts over a 50 year time-frame are subject to increasing uncertainty due to the implicit assumptions concerning major institutions, their behavior, general societal behavior, and a wide range of other surprises. Thus, the concept of uncertainty as it is applied for long-term assessments is far more important than for short-term assessments.

Relationship Between Modeler and User

Models and model output are often found irrelevant to the ultimate decision-making process. To the extent that the application of models for environmental assessments is at the discretion of OTI, it is important that OTI design model use so as to increase their utility, attractiveness, and relevance to policy decision-makers. Four specific recommendations were identified in this area.

- Use of publicly recognizable units

Solicited inputs and model outputs should be converted into units pertinent to public decision-making. For example, tons of SO₂ per state per unit may not be meaningful to decision-makers. Emission data should be converted to populations at risk or to other human health related indicators. Where these conversions cannot be readily made, it is recommended that future investment in model design be redirected away from expanding the capacity, scope or quality of the model calculations toward a revision in model operation, data input, and computation. This change will increase compatibility between model output form and that desired for decision-making.

- Incorporate uncertainty into model operation and present uncertainty measures with model results

All major economic/environment models incorporate some degree of uncertainty. Models can be made normative to remove some sources of uncertainty from influencing the analysis. Further, the use of a scenario approach substantially reduces the uncertainty associated with model calculation if the scenario is put in the form: "If population, GNP, oil prices, etc., are as forecasted by the scenario, then the following environmental impacts will result."

However, uncertainty in model results still exists. It is recommended that this uncertainty be recognized, and that its sources be identified, e.g., scenario, data base, model linkages, etc., and incorporated into model output. A result numerically forecasting a seven percent reduction in NO_x for the year 2000 does not, in fact, forecast exactly within a range between two unknown limits with seven percent as a most likely value. A pertinent statistical question is whether the seven percent result is significantly different from zero. Yet current model output cannot provide this information. Such an analysis requires the statistical incorporation of uncertainty (data and computational relationships) into the model calculations. In fact, incorporation of uncertainty into model results is a critical step in increasing the real value of the model for decision-making.

There were more specific recommendations made. The first of these is that the presentation of a single point value in model output be replaced by a range of probable values with a listing of the factors that generated the uncertainty and an estimate of the time and effort required to improve the estimate. The second of these recommendations is to publish a comprehensive list of model and data base assumptions and to encourage open review of these assumptions and their associated uncertainty.

- Foster decision-makers' confidence in model results

This is at best a nebulous factor to address and intuitively requires long-term successful exposure of the decision-maker to economic and environmental models. However, three specific recommendations were made which will tend to increase decision-maker's trust in OTI model results:

- 1) Increase the availability and detail of documentation on OTI model systems.
- 2) Encourage and support scientific, congressional staff and decision-maker critical review of SEAS operation, structure, assumptions and supporting data bases. This should include publishing details of the model in the open literature.

- 3) Reduce complex model elements to a series of coupled small single purpose models that can easily be substantiated or verified.

- Design the form of output to match decision-making needs.

Model output currently is provided in extensive tabular form. The use of this output would be greatly enhanced if: 1) output is interpreted and converted into essential information prior to release; 2) output can be disaggregated over a variety of subgroups, e.g., income, age, spatial, location, etc., as best suits the needs of a specific analysis; and 3) emphasis is placed on condensation of information into as compact a form as possible without sacrificing meaning or clarity. Graphical and mapping displays are ideally suited for this purpose and are recommended for increased use in OTI assessments.

It was felt by the workshop participants that the modeler has a moral obligation to take such steps as are feasible to minimize the opportunity for misuse of model results. Several specific recommendations were made to this end. These are:

- Decrease the separation between modeler and decision-maker.

In order to reduce misuse and misinterpretation of model results, it is desirable to decrease the separation between the modeler and the decision-maker (ultimate user). This can be accomplished by removing the institutional layers (buffers) between user and modeler; by promoting an ongoing dialogue between user and modeler; by using this dialogue to impress upon the user the strength and frailties of the model(s); and by insisting upon professional integrity in the interpretation and application of model results.

- Design format of results to minimize misuse.

A large part of model misuse stems from improper interpretation of model output. Assumptions, limitations, approximations in linkages and methodologies, and input data inaccuracies are often

forgotten in the face of a seemingly precise numerical output. However, that output contains real information only in light of all the assumptions and uncertainties inherent in its calculation. It is therefore recommended that, as a minimum, the following steps be undertaken by the modeler. Model output should be interpreted and converted into relevant information before release. Released information should be tailored to the needs of the user for each specific model application. Detailed model documentation should be prepared and distributed to potential users.

Small, simple models discourage misuse.

Model structure and complexity significantly affect the tendency to misuse model results. Small, simple, single purpose models discourage misuse, while large multi-objective complex models present an unending opportunity for misuse and misinterpretation. It is recommended that OTI emphasizes the use of small, simple models linked to perform required computations and that these linked models be operated in a hierarchical system.

Summary

Working group discussion centered on three general areas. The most important of these areas was regional involvement in the assessment process. The group concluded that states are the best level for obtaining this direct regional involvement. State involvement should include both the input of state goals and policies into initial siting and disaggregation processes and an involvement in the impact interpretation and evaluation procedures. The second general area was the design of assessment programs. Two sub-areas were identified and discussed: analysis of environmentally designed scenarios, and identification of the appropriate timeframe for policy analysis studies. Specific recommendations were made in each of these areas. The final general area addressed by the group was the relationship between the user (decision-maker) and the model, or modeler. Included were discussions and recommendations for making models and their outputs more attractive to decision-makers and for guarding against misuse of model results by these policy analysts.

Appendix A

Summary of Workshop Recommendations

MODEL STRUCTURE

Long-Term Recommendations:

- Develop a core set of related models that are modular, dynamic and consistent.
- Form an advisory group to establish the appropriate methodological framework of models.
- Establish a model system with an inter-industry accounting framework and inter-regional linkages among the different sectors of the economy and environment.
- Require adequate up-to-date documentation.

Short-Term Recommendations

- Improve base year data (national and regional) of the current OTI models.
- Improve accounting framework (energy/economic) of the current OTI models.

MEASUREMENT ISSUES AND APPROACHES

Data System and Source Recommendations:

- Develop and maintain an integrated system of socioeconomic, energy and environmental data.
- Interact more effectively with EIA and other statistical agencies that collect data.
- Acquire detailed environmental and technology characterization data.
- Include statistical estimates of the uncertainties in data input and model output.

Procedural Recommendations:

- Develop simpler models congruent with real measurements and not "synthetic" data.
- Sponsor an Energy Statistics Committee at the National Academy of Sciences.
- Emphasize independent model and data validation and verification.

USE OF MODELS FOR POLICY ANALYSIS

Regional Involvement in Assessment Process:

- Incorporate state-level inputs into OTI siting and disaggregation systems.
- Develop, in cooperation with state agencies, a common energy accounting system.
- Establish a hierarchical assessment methodology.
- Develop a taxonomy of environmental impacts and the spatial and temporal scales best suited for their assessment.

Design of Assessment Programs:

- Develop environmentally significant alternative energy and economic scenarios.
- Estimate the total and marginal costs of environmental standards and policies.
- Use short-term studies to address specific tactical questions, e.g., standards compliance.
- Base long-term assessments on the full cycle of a major energy facility.

Relationship Between Modeler and User:

- Convert inputs and model outputs into units pertinent to decisionmaking.
- Incorporate uncertainty into model operation and present the levels of uncertainty with model results.
- Foster decision-makers' confidence in model results by increasing availability and documentation on OTI model systems.
- Design the form of output to match decision-making needs.
- Decrease the separation between the modeler and the decision-maker.
- Design format of model results to minimize their misuse.

Appendix B

Relationships Between National and Regional Economic Models: Alternative Perspectives

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Introduction

The growing demand for regional and multiregional economic models reflects the increasing awareness that attention to spatial and regional factors is crucial in the design and implementation of national policies pertaining to energy, environment, inflation, productivity and employment. Theory and empirical evidence clearly suggest that the performance of the national economy, e.g., in terms of the levels of output, employment income, prices, or energy output, etc. is not independent of the variations in regional supply and demand factors (Richardson 1973, Thirlwell, 1968, Kort 1979, Courbis 1979, Honea, Vogt and Hillsman 1979, Lakshmanan 1980).

For example, if production factors in some sectors move from a lagging region to a growing region characterized by higher productivity, the overall national output may be higher than otherwise would be the case. Again, the more heterogeneous and polarized spatial development for the French economy as compared to the German is believed to account for the greater propensity to inflation in France (Courbis 1978). Further, it has been suggested that regional supply factors, (e.g., water supply, transportation facilities in the Southwest) U. S. poses serious constraints on actively pursued national energy policies requiring switching to coal conversion for power generation (Honea, Vogt, and Hillsman 1979).

As a consequence, there has been a recent surge in the development of multiregional econometric and input-output models designed for the analysis of a wide variety of national public policies relating to transportation investments, energy development, environmental standards, welfare reform, and land management (Harris 1973, Olson and Allaman 1978, Golleday and Haveman 1977, Ballard and Wendling 1978, Courbis 1978, Courbis 1979). These various operational models differ in their theoretical structure, geographical and sectoral disaggregation, data richness

and degree of policy coverage. However, they share one attribute: they all exhibit two components -- a regional and a national model. Since the different regions in the multiregional model exhaust the national space, economic influences and constraints operate in both directions -- from the nation to the regions and from a region to other regions and the nation. The national and regional components of a multiregional model exist to insure that these interrelations operate in a consistent fashion.

The two way intra-national flows between the national and regional models are implemented with varying degrees of sophistication in the different models. The most common version postulates a unidirectional nation-to-region relationship or 'top down' view. The national model determines the key national variables independent of regional variations in demand and supply. The regional disaggregation is merely a recipient of information from the national model, allocating and interpreting national variables at the regional level. Regional variables are aggregated and averaged to conform to national values of these variables and in this sense are "driven by" the national model. This is exemplified by the top down relationship between INFORUM and REGION model in the SEAS model and many major modeling efforts (Lakshmanan et al., 1977, House 1977, Harris 1973, Olson et al., 1977).

An alternate approach is to determine explicitly the impact of regional and spatial factors on national development, by reversing the direction of the relationships from region to nation. Regional variables are endogenously determined by the regional model and national variables represent mere aggregations of regional values. This is the 'bottom up' approach, and has not yet been operationalized in this form.

A third approach is to structure the relationships between national and regional model is termed as 'hybrid' (Bolton 1979). A two way cause-effect relationship and division of labor exist between national and regional models. Some variables, e.g., housing, labor force, etc., are determined at the national level independent of regional factors. The REGINA model in France and the NRIES model in the U. S. appear to be the only operational models of the hybrid variety (Courbis 1978, Courbis 1979, Ballard and Wendling 1978, Ballard and Gustley 1980).

While hybrid models represent a theoretically attractive alternative, further significant developments are contingent on release from two constraints. First is the absence or poor quality of many types of regional data for the bottom up approach often necessitating the use of the top down approach. The more serious constraint is the need for greater understanding of the cause-effect relationships and preference structures of decision agents that constitute the dynamic feedback loops in a national-regional economic system.

Neoclassical theory, the current source of our hypotheses regarding these feedback loops, has focused on self organizing market behavior with given structures. There has been recently a growing view that the market economy is more of a self organizing system, a system that can and does modify its own structure and programming in the course of and as a result of its own operations (Marris and Mueller 1980, Williamson 1970, Caves 1980). The main features of this approach are to treat markets on the one hand and administrative organizations or "hierarchies" on the other as alternative modes of production. Hierarchical structures brought about by elements of bounded rationality, and control loss, in large (private and public) organizations in a multiregional economy influence the economic performance of firms and the market they operate in (Caves 1980).

In classical location theory, for instance, the profit maximizing location is determined at the point of minimum production costs. Recent developments in neoclassical production theory would allow profit maximizing location decisions to take into account significant substitution possibilities between various factor inputs, so that input prices and quantities can be obtained simultaneously with locations (Christensen, Jorgensen and Law 1973, Berndt and Wood 1975, Lakshmanan 1979). Industrial location decisions by large multiplant firms, on the other hand, may reflect, in addition, the effects of business organizational structure and a desire to balance portfolios of location risks among the various regions. Thus the relationship between firms and their market environment are of interest in helping to delineate more fully the interrelationship between different parts of a multiregional system.

A related area of inquiry in economic geography and business administration pertains to the study of space-time systems which describe regional or national phenomena in locational specificity and (spatial-temporal) relativity (Hagerstrand 1975, Bennett and Chorley 1978). The key notion here is that socioeconomic systems should be analyzed both in space and time simultaneously. Space-time systems partitioned into a number of interacting regions can be viewed as control systems manipulated by a set of regulators and changes in system structure (reorganization). Such a multiregional system could be optimized towards overall system goals and subject to regional targets in the form of a hierarchical control problem. A number of regional economic policy issues are amenable to such methods of decomposition.

These relations between decision agents and their market environment in a multiregional system lie at the intersection between industrial organizational behavior, business administration and regional space-time systems in economic geography. The paper attempts to survey, synthesize, and report on research from these disciplinary bases. The objective is to elucidate the rich web of relationships in a national-regional interacting system.

The paper begins with a review of the top down and bottom up approaches as they have evolved in the area of management theory and industrial organization. Next it presents some promising notions from the literature of space-time systems. Finally, it explores the implications of these research findings in other disciplines on structuring hybrid multiregional models embodying these relationships.

"Top Down" and "Bottom Up" Approaches in Management Theory

The first mention of top down and bottom up approaches pertains to the work of Henri Fayol and Frederick Winston Taylor in the area of Management Theory (Miner 1978). In this context, top down and bottom up approaches reflect the divergence in perspectives of the principal actors, Fayol and Taylor. Fayol was a top manager of his corporation and thus his observations of the managerial function were made on the management level directed from the top down. Taylor, on the other hand, rose from an apprentice to the higher levels of management and thus his work looked at management principles primarily from the bottom up, starting on the shop level.

Taylor's approach, and those of his followers Henry L. Gantt, Frank and Lillian Gilbreth, among others, was aimed at the "scientific" delineation of highly specific, specialized tasks. The factor that was supposed to link up and integrate this diversity of specialized tasks and roles was that of mutuality of interests. People in this movement reasoned this mutuality of interests stemmed from the compatibility in workers - management objectives. Fayol's approach, however, was more teleological in nature. His concerns were more in enunciating the principles governing managerial roles and functions. The tacit assumption being that once the managerial role is fully defined, other roles fall into place as natural consequences of the managerial role. In essence then, the primary difference between the top down and bottom up approach as originally conceived, is that of emphasis and starting point. Top down approaches start with and emphasize the managerial roles whereas bottom up approaches start with the emphasis on the specific, specialized tasks of the shop floor worker.

With the increasing complexities of the organizational environment in the post - industrial revolution era, large organizations most universally became hierarchial in nature (Simon 1960, p. 40). By hierarchial is meant that the organization is composed of a vertical arrangement of subsystems, and where higher level subsystems must depend upon the performance of lower level subsystems (Freedland 1973).

Two key prototype hierarchical structures - functional and multi-divisional (MD) -- are developed depending upon the degree of diversification and geographic diversification (Williamson 1970). With increasing complexity, the firms switch to MD type, given problems of bounded rationality, control loss and redundant communication.

Although a hierarchical decentralized structure offers some desirable characteristics it also creates coordination and control problems. A hierarchical structure tends to break overall organizational goals down into subgoals and then distributes them over several levels and decision making units (Cyert and March, 1963, p. 19). This process can lead to conflicts within the organization. A major source of conflict is when limited resources such as capital, labor, raw materials, energy etc.,

must be distributed over several levels and among several units within a level. Since each decision making unit requires certain resources in order to carry on its activities, it is common for subordinate units to compete with each other for any resources which must be shared. Organizational decision processes involving the resolution of conflicts stemming from the allocation of scarce shared resources are commonly referred to as resource allocation processes (Freedland 1975, Hurwicz 1972, Ruefli 1974). Resource allocation processes are generally characterized as follows:

Initially, there exists a set of inputs to the superordinate (highest) level. These inputs are derived from both external and internal stimuli and data bases. The external inputs usually represent requirements or goals which are either explicitly or implicitly imposed on the organization by external forces; for example, economic conditions may call for production cutbacks, competition may dictate certain pricing strategies or norms, the deferral or local governments might require that certain environmental pollution standards be met, etc. The internal inputs typically include information on the availability and utilization of resources such as money, labor, plant and facilities, raw materials, etc., and pro forma and actual operating and capital budgets. Internal inputs also include the superordinates receiving and processing information about the subordinates requirements of shared resources, anticipated performances, likely targets, etc.

Given these exogenous inputs, the information from the units below, and the subordinate's own expectations, the superordinate arrives at a utility function and a set of constraints. On the basis of this utility function and subject to the set of constraints that determine the solution space, the superordinate (or center) tentatively selects a program of resource allocations for the subordinates in the second level. This program, generally consisting of a set of resource budgets and profit plans, and additional coordination information are communicated to the aforementioned subordinates. The information used for coordination may be in the form of binding constraints on subordinate behavior; or incentives/penalties for the attainment or non-attainment of priority targets; or information clarifying the superordinate's objectives.

A subordinate level two goes through, more or less, the same information gathering, problem solving and information communication process as the superordinate, the only difference being that the directives received by the subordinate from the superordinate are analogous to the superordinates' exogenous inputs.

This process is an iterative one (Hurwicz 1972 and 1973). It begins with the highest level decision unit selecting a program of resource allocations and then transmitting this program along with coordination information to each subordinate unit at the second unit. Each subordinate unit at the second level then solves its allocation problem and sends appropriate information about its problem solution along with coordination information to subordinates at level three. This continues until the bottom levels are reached at which time the information flow reverses itself and starts flowing up through the hierarchy until it reaches the superordinate at level one. Kornai (1971) calls this upward flow of information counter planning.

During the counter planning process, the information at each decision unit is integrated and aggregated so that the superordinate, at the very top, has summary information about the ramifications of the tentative budgets or programs assigned at the beginning of the given cycle. The superordinate uses this information to arrive at a new set of tentative budgets and the entire process repeats itself and starts flowing up through the hierarchy until it reaches the superordinate at level one. Kornai (1971) calls this upward flow of information counter planning.

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The question is, is this resource allocation process a top down approach or a bottom up approach? To answer this question we have to take recourse to three constructs first enunciated by Sweeney, et al (1978).

These constructs are as follows:

The first construct is that of an overall organization (or system) problem. This is not a problem faced by any individual or groups of individuals in the organization. Rather, it is the problem that is solved by the collective entity called the organization. Such a problem need not be stated explicitly, but, if an organization is defined as a system or entity unto itself, then it must exist implicitly.

The second construct is that of an organization structure. Operationally, organization structure may be defined as the collection of subsystems, within the system called the organization, together with how these subsystems are arranged and related to one another both vertically and horizontally. Each of these subsystems also has its own problem which shall be referred to as subproblems.

The third construct is that of a coordination mechanism. The coordination mechanism is both a catalyst that energizes the system and also a means for conflict resolution between subsystems. The mechanism includes a specification of which subsystems make what decisions, the type of information to be exchanged by each subsystem and a means for determining when the plans of the various subsystems have been suitably coordinated.

Given these constructs, we can now differentiate between top down and bottom up approaches to the previously specified resource allocation process.

The top down approach, also known as the decomposition approach (Freeland 1973, Hurwicz 1973, Sweeney, Winkofsky, Roy and Baker 1978) and the classical approach (Ruefli 1974), starts with the assumption that the organization problem and the organization structure is fully defined. Thus the problem boils down to one of finding the "best" coordination mechanism. This approach became very popular subsequent to Dantzig-Wolfe's formulation of the decomposition principle (Dantzig and Wolfe 1960) and Bender's partitioning procedure (Benders 1962). Baumol and Fabian (1964) saw the similarities between the block angular structure of the Dantzig-Wolfe linear program and the organizational structure of a variety of decentralized, hierarchical planning situations. The dual multipliers

in the Dantzig-Wolfe formulation could be interpreted as the subunit's marginal costs for the shared resources. A format common for the mathematical statement of the organization problem, which, it should be noted, is fully defined, is given below:

$$\max C_1 X_1 + C_2 X_2 + \dots, C_p X_p$$

s.t.

$$A_1 X_1 + A_2 X_2 + \dots + A_p X_p = b_0$$

$$B_1 X_1 \leq b_1$$

$$B_2 X_2 \leq b_2$$

$$\dots B_p X_p \leq b_p$$

$$X_i \geq 0, i$$

where

C_i is an n_i component vector,

X_i is an n_i component vector,

A_i is an $m \times n$ dimensional technology matrix for the shared resources

B_i is an $m_i \times n_i$ dimensional technology matrix pertaining to the
solely internal resources

b_i is an m_i component vector of resources.

The usual top down approach is to create $p+1$ subproblems, one for each of the p sets of activities X_i (these subproblems are often called infimal subproblems, and another for coordinating these p subproblem solutions in such a fashion that the constraints of the organizational problem are satisfied. This last problem is often called supremal subproblem. Coordination, in a mathematical sense, is achieved by passing parameters from the supremal to the infimal subproblem and vice versa.

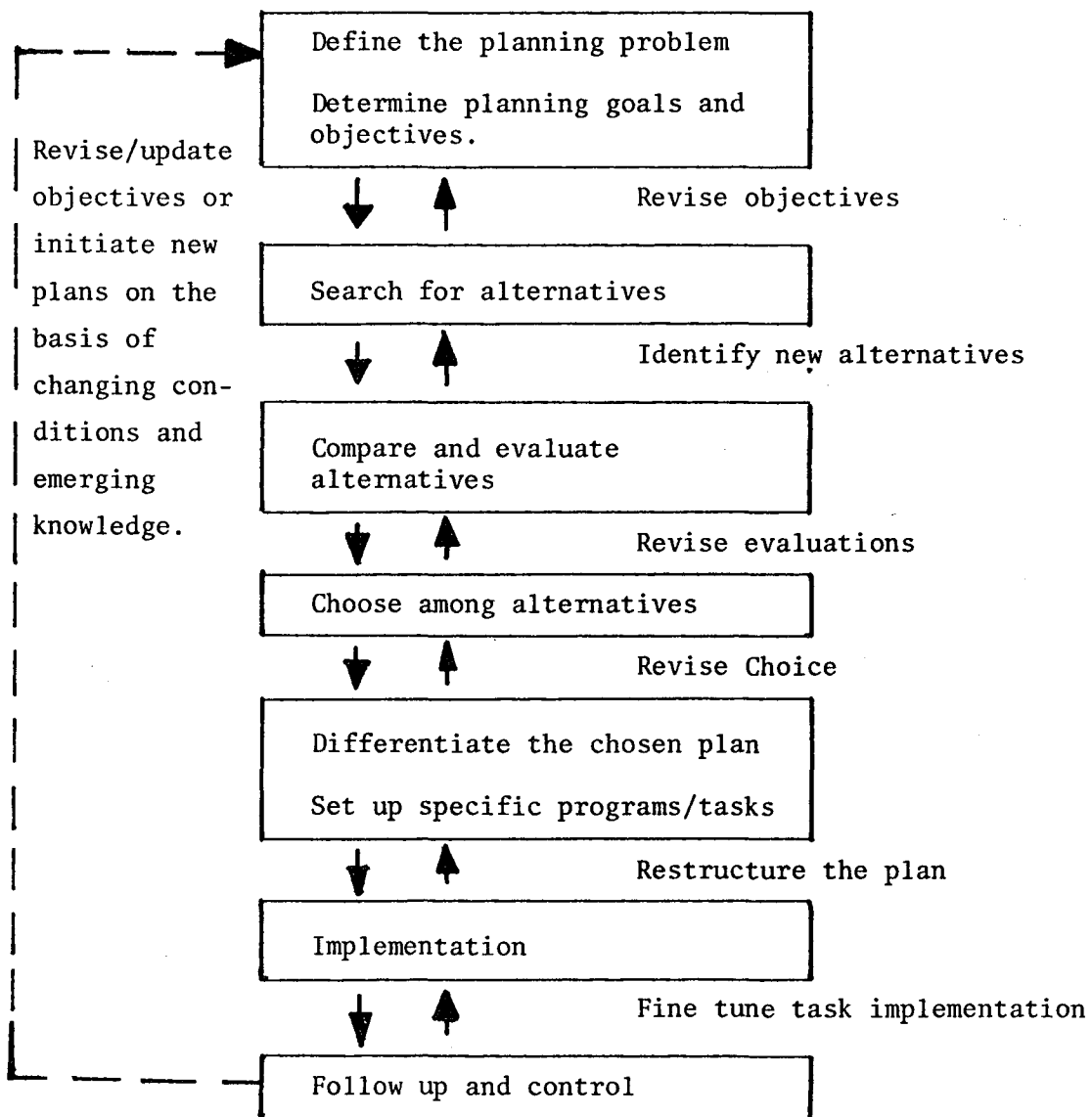
The type of information passed usually consists of prices, e.g., transfer prices, opportunity costs, marginal costs, etc., for the shared resources or amounts of shared resources either available or required. If the coordination mechanism calls for the supremal unit to charge the infimal units for the shared resources either available or required. If the coordination mechanism calls for the supremal unit to charge the infimal units for the shared resources used, then the mechanism is called price directive. Most, if not all, of the price directive genre of mechanisms have their roots in the Dantzig-Wolfe decomposition principle. These mechanisms are also known as dual metric. If the supremal unit, however, allocates resources to the infimal units, the mechanism is called resources directive. The mechanisms of the resource directive genre rely heavily on Bender's partitioning procedure. These mechanisms are also known as primal methods. Hybrid methods involve some price direction and some resource direction. Since top down approaches assume the organization problem and organization structure as either given or what ought to be, the focus of this approach is on the development of coordination mechanisms or algorithms. This emphasis on algorithm development has spawned a variety of mechanisms. A number of examples of price directive mechanisms (Abel-Khalik and Lusk, 1971, Aoki 1971, Atkins 1973, Cassidy, Kirby and Raike 1971, Charnes, Clower and Kortanek 1967, Hass 1968, Heal 1971, Jennergren 1973, Krouse 1972, Weitzman 1970); of resource directive mechanisms (Geoffrion 1970, Kornai and Liptak 1965, Silverman 1972, Ten Kate 1972 and Zschau 1966) as well as of hybrid mechanisms (Atkins 1973, and Ennuste 1973) abound.

The bottom up approach, also known as the composition approach (Sweeney, Winkofsky, Roy and Baker 1978) and the behavioral approach (Ruefli, 1974) commences with the development of the problems solved by the separate subunits themselves. In this approach the organization problem is undefined, and a part of the organization structure, the statement of how the subunits are arranged and related to one another, is also undefined. In addition, the coordination mechanism also has to be specified. Due to this amorphous nature of the bottom up approach, there have been very few attempts at using this approach. In general, the models (Freeland, 1973, Roy and Lakshmanan 1980, Ruefli 1971) that have used this approach try to couple the coordination mechanism with a gradual

unfolding of the organization problem for assumed organization structures. In Roy and Lakshmanan (1980) the organization problem, even at the end, is not fully known.

Having traced the evolution of the top down and bottom up approaches from their origination with Fayol and Taylor to their present day connotation, the question is, how do the present day top down and bottom up approaches jibe with the planning process per se. In order to answer this question let us briefly highlight some of the salient features of the planning process. Figure 1 presents a schematic overview of the planning process.

Figure 1. Overview of the Planning Process



The planning problem may be dichotomized into two sets of problems; well-structured and ill-structured problems. This dichotomization depends, to a large extent, on the relative certainty of outcome preferences and cause and effect interrelationships inherent in the problem situation (Newell 1968). Table 1 shows the relational nature of the problem situation and the appropriate decision strategy.

Table 1

Problem Context and Corresponding Decision Strategies

		Preferences regarding possible outcomes	
Beliefs about Cause and effect	Certain	Computational Strategy	Compromise Strategy
Interrelationships	Uncertain	Judgemental Strategy	Inspirational Strategy

Well-structured problems are those in which there is a relatively high degree of certainty regarding both beliefs about cause and effect interrelationships and outcome preferences. Thus the appropriate decision strategy, for such problems, is "programmed" to the extent that a definite procedure has been or can be worked out (Ebert and Mitchell 1975, Harrison 1975, Newell 1968, and Van Gigch 1978). This approach is compatible with the "computational strategy" block of Table 1. In general, well-structured problems are also programmed to the extent that they are repetitive and routine (Mintzberg, Raisinghani and Tehoret 1976, Mockler 1973, Simon 1960).

Ill-structured problems on the other hand are "non-programmed" to the extent that they are relatively novel (Ebert and Mitchell 1975, Harrison 1975, Mintzberg, Raisinghani and Theoret 1976, Van Gigch 1978). There is no established method for handling the problem because it has not arisen before, or because its precise nature and structure are

elusive or complex, or because it is so important that it deserves a custom-tailored treatment (Simon 1960, p. 6). Thus, the appropriate decision strategy would likely depend on compromise judgment or inspiration.

Decision strategies can also be characterized by the following two criteria; generality and power (Van Gigch 1978).

Generality, in relative sense, refers to the variety of problems over which the decision strategy is applicable and the type of information demands made on the problem. The very general strategies are applicable over a wide variety of problem situations and impose very small informational demands.

Power, also in relative sense, refers to the ability of the method to deliver problem solutions. Usually, this ability is gauged in terms of the probability of attaining a solution that is close to an optimum. In addition, power also depends on the efficiency of resource utilization in obtaining solutions.

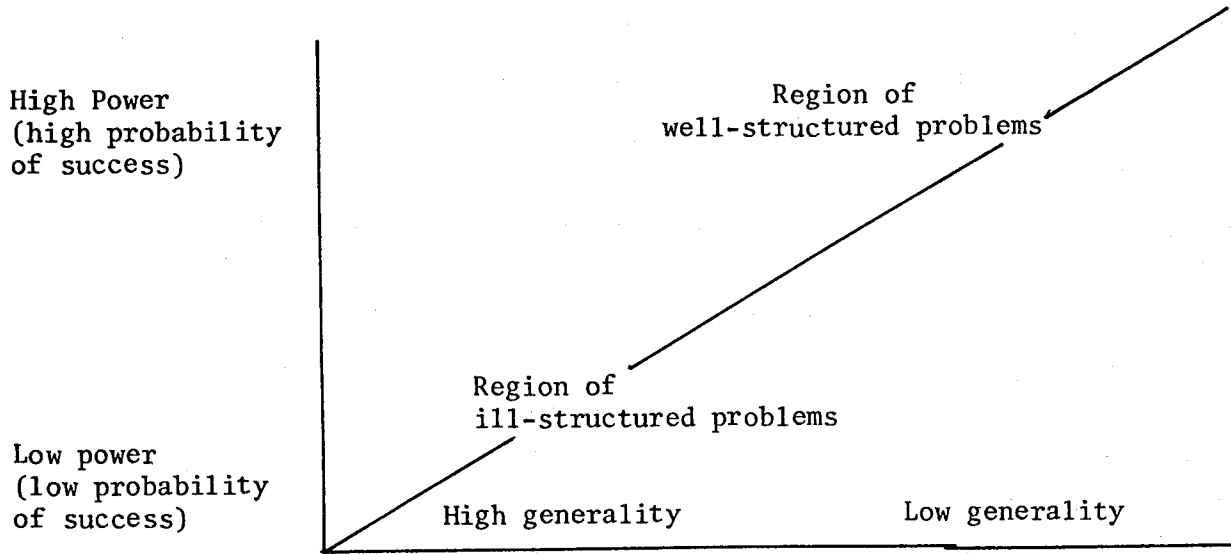
The relationships between generality, power, and problem structure can be depicted as in Figure 2.

In Figure 2, at one end of the spectrum, when a problem is ill-structured, methods of high generality need to be employed. These methods are likely to be low powered with low probabilities of successfully attaining the optimal solution. These methods make weak demands on the environment, which means that the problem statement requires relatively few conditions to be met and that information provided is vague. Information is vague in the sense that it is specified in a range or band and is not very definite (Cleland and King 1972).

At the other end of the spectrum, when a problem is well-structured, methods of low generality are usually employed in its solution. These methods are relatively high powered with high probabilities of successfully attaining the optimal solution. At this end, problems are more specific, better defined and the information provided must fit the stringent conditions of the problem statement.

FIGURE 2

THE SPECTRUM OF POWER AND GENERALITY IN PROBLEM-SOLVING



In concluding this section we see that the top down approach, with its emphasis on algorithm development, can be readily identified as computational strategies. Thus, the top down approach appears applicable only to well-structured planning situations. Situations in which beliefs about cause and effect relationships are pretty definite and preferences, regarding possible outcomes, fully determined.

In contrast, the bottom up approach would appear to be applicable to ill-structured planning situations. In theory this is quite true. In practice, however, the bottom up approaches developed to date may be identified as compromise strategies.

In closing this section, we would like to note that the top down and bottom up approaches, emanating from an organizational set up, are essentially static in nature. The models developed in this area ignore the dynamic feedback loops in the planning process. Thus in the next section we look at space-time continuums approaches as methodology permitting the incorporation of adaptive dynamic frameworks into the planning calculus.

Space-Time Socio-Economic Systems

An analogous but broader multi-disciplinary development in the analysis of complexity is the systems approach. The framework and analytical techniques developed in this approach are relevant to the analysis of a multiregional economy viewed as a composite of individuals, firms and organizations.

Traditionally, national or multiregional models, incorporating hundreds of equations attempt to reproduce the behavior and time paths of a set of economic performance or endogenous variables from a set of exogenous variables utilizing a set of behavior assumptions (transfer function system operators). The purpose is to produce estimates that facilitate the formulation of public policy. Certain economic policy instruments identified by macroeconomic models have been successfully used in this fashion to manage selected attributes of the economy. However, there are frequently not enough policy instruments available to permit the simultaneous achievement of several policy objectives (Tinbergen 1937). Further a multiregional economic system is complicated and comprised of far too many feedback loops, the structures of which are only dimly known.

Thus a general problem of macroeconomic and multiregional models is their submergence within their general equations of the reality of decision making processes especially their sociopolitical and power bases (Bennett and Chorley 1978, Kuhn 1974). The economic control system can neither be looked at partially (as separate policy problems) nor viewed in isolation from social, political or ideological goals and constraints. The spatial character of regional economic activity derives from overlapping economic, sociopolitical, and administrative networks. The regional location of economic activity is thus partly a result of the economics of location in the Isard sense, partly the result of political boundaries and administrative structure.

There are no easy ways of incorporating such realism in the decision structures of multiregional models. The difficulties of aggregating individual utility functions to community and social levels have been highlighted by Arrow's impossibility theorem (Arrow 1951). The notion of Kuhn that change in socioeconomic systems is a function of processes

such as decay, emergence and learning is too complex to be incorporated currently in multiregional models (Kuhn 1974). Decay relates to the hierarchical disintegration of social organization levels. Emergence refers to the appearance of newer organizational levels characterized by increase of information, differentiation and effectiveness. Learning involves the generation of new behavioral modes, goals and means of action.

For multiregional models, then, considerations imply a change in the nature of explanation. The resulting notion is one of indeterminacy of state and indeterminacy of measurement in large scale multiregional models. Human and organizational intervention in economic systems (of considerable time and space extent) introduces further the indeterminacies of socioeconomic control objectives. As Leibenstein has pointed out, controllers of (private or public) hierarchical organizations receive and translate signals from outside in order to induce performance from the inside. In the process, however, these individuals, motivated by "cooperative-conflict" considerations may carry out these functions with a number of distortions (quoted in Marris and Mueller 1980, p. 38). One needs to ask: What are the political and social implications of control and for whom and by whom is the control exercised? Goals, organizational structures and microeconomic behavior thus interact in unsimple ways in a multiregional system.

The internal mechanisms of multiregional systems are complex and cannot be reproduced by simple models which allow individual stimulus-response situations to be followed. Instead a synthetic (system) mathematical structure must often be utilized as a consequence of which the outputs of models may become unpredictable -- or counter intuitive.

Recent developments in the literature on space-time control systems are helpful in enriching the structure of multiregional models in the above areas. Till recently, economic systems have been analyzed either in terms of either dynamic (or temporal) content, e.g., national macroeconomic policy's or in terms of spatial control, e.g., spatial lay out of facilities such as hospitals, police stations, shipping centers or allocation of economic sectors in economic policy, (Bennett and Chorley 1978, Scott 1971, Mennes, Tinbergen and Waardenburg 1969).

Temporal control of economic systems with recognizable centers of activity does not take into account the spatially distributed effects in

the economy which are viewed as remaining constant over the planning time horizon. In many cases, the spatial distribution effects generate the specific lead, lagged response attributes of the economy. It has been observed that regions differ significantly in their responses to national cyclical changes, though the range of leads and lags is relatively narrow (Thirlwell 1966). Regions in the U.S. differ significantly with respect to the amplitude of their cycle. Regions are consistent in their behavior during the cycle, repeating their amplitude magnitudes through successive cycles some generally leading (Northeast) and other lagging (West) behind the nation. If public works expenditures for instance, are undertaken during a recessionary period, they are unlikely to absorb the total unemployed in the nation (Vaughan 1976). Funds must be distributed among regions in a way that maximized there countercyclical impact. Consequently, dynamic control of economic systems without taking into account spatial aspects can be misleading.

On the other hand, there are numerous instances of spatial control decisions of the once-and-for-all static variety pertaining to allocation and location of public and private facilities and networks (Scott 1971). The choice of locations for fire stations, retail shipping centers, cultural or educational facilities or administrative center and the design of flow networks to minimize interaction costs are illustrations of this optimization problem (Church and Reville 1974).

A variation of this approach is a model of cost minimization in development planning in Mexico involving optimal allocation of investment with respect to spatial cost differentials in production and demand (Mennes, Tinbergen and Waardenburg 1969). However, these models are negligent of the temporal dimension.

Recent work treating space-time interaction systems considers simultaneous control of all regions to independent targets by independent controllers (Schoeffler 1971). This gives the form of hierarchical or nested control problems. Such systems which can be addressed by a number of decomposition devices.

Structural decomposition involves the partitioning of economic system equations into separate sets for each region, each with separate target

levels of reference input and a separate set of controllers. Influence decomposition involves the partitioning of control system itself into levels of control system between subsystems and regions. This implies the use of a control design based upon the hierarchy of control policy (Bennett and Chorley 1978). Control decomposition is a third method of addressing control problems by the mathematics of the optimization solution itself (goal coordination or model coordination).

A key point to note is that often these approaches represent a planning or control framework as contrasted with spatial econometric 'partial' choice problems, e.g., size and location of facilities or transport networks, under *ceteris paribus* assumptions. In the regional planning or the system approach, the focus is on identifying a coherent preference system the constraints that need to be imposed and the coordination between public decision agents tends to assure the attainment of a sufficiently efficient system.

Concluding Comments

In a very influential article a decade ago, Klein had suggested a format for regional econometric models analogous to "satellite" industry models, recommending models which can be plugged into national models and using exogenous variables predicted by the latter (Klein 1969). Subsequent work has achieved more industrial disaggregation and less of the nation-income account-type structure for regional models (largely due to data base constraints). However, the regional modeling approach has remained largely Klein's original 'top down' format forecasting the nation to each of the regions.

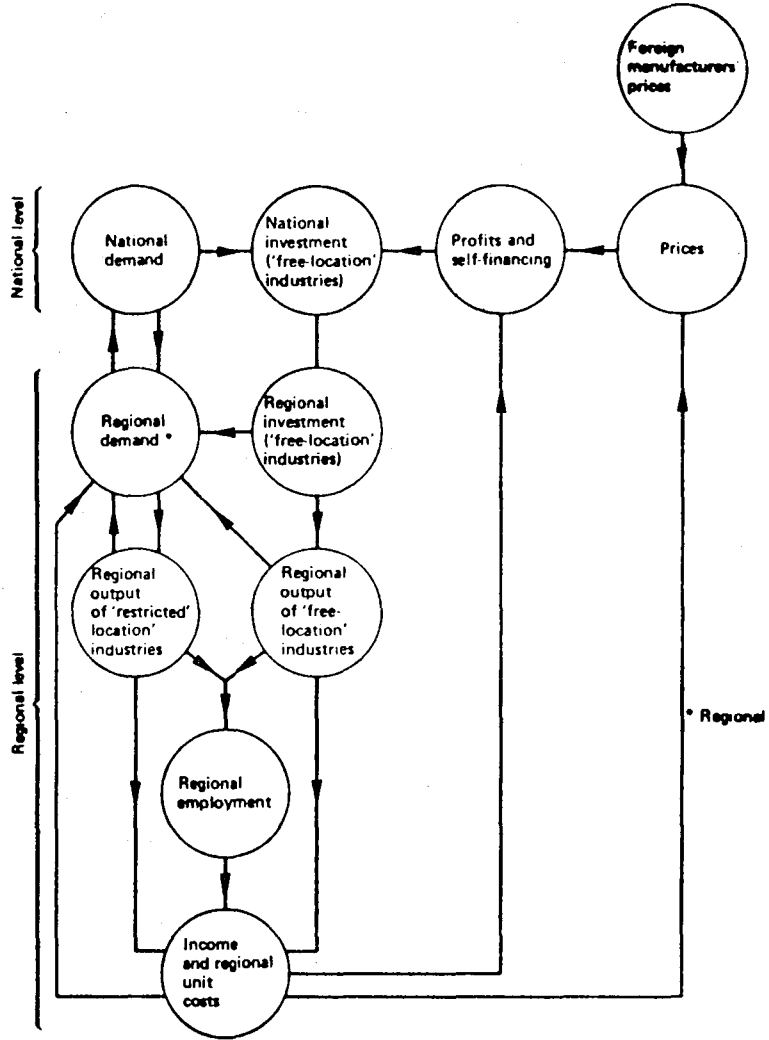
The 'performance' of demand type macroeconomic model that linked top down to regional models was probably acceptable in the fifties and sixties when most prices were trending together. In the last decade or more, supply side effects at the regional level have become far too significant to ignore. Regional variations in production factors, energy and non-energy natural resources, and environmental considerations affect the elasticity of supply considerably among regions. Labor market adjustments, migration, labor force participation rates, investment supply, etc. need to be modeled at the regional level in such a fashion that they impact on national development.

This point about the need for increased attention to the supply side has been made earlier (Bolton 1979, Lakshmanan 1979). Its relevance here is that such attention is an important component of the two way relationship between national and regional models. Another component is clearly demand side factors at the regional level. Demand factors include the effects of regional household consumption patterns deriving from income and urbanization variations, household residential investment and the like. A multiregional model that incorporates such demand and supply side effects from the regions to the nation and certain relationships, e.g., interest rates, some prices and investment, exports, imports, etc., from the nation to the region are hybrid models. A noteworthy example of such hybrid model is the French REGINA model shown in Figure 3, which captures some of the key two directional relationships. National demand and investment affect regional demand and output, while regional income and cost characteristics in turn affect prices and profitability and investment at the national level. The major point of the paper has been that while hybrid multiregional models are desirable, further significant developments are dependent upon increased knowledge of the two way relationships and preference structures of decision agents that constitute the multiregional economic system. While economic geographers, regional scientists, and economists have made important contributions to this field, this survey has focused on evidence from other fields-- management theory, business organizational behavior, and systems theory.

A number of conclusions result. First, the structures of markets in a multiregional context are affected by the organizational options open to private and public organizations. Understanding such organizations or hierarchies should parallel the study of structures of markets.

Second, analytical approaches developed in management theory and socioeconomic space-time systems theory to the study of relationships between decision agents at different levels in a multiregional national system are relevant to future development of hybrid models. The theoretical contributions are highly informative where the organizational situations are well-structured, but merely tantalizing in less-structured contexts.

FIGURE 3
INTERACTION BETWEEN NATIONAL FACTORS AND REGIONAL EQUILIBRIUM
IN THE REGINA MODEL



Source: Courbis, 1978.

Third, the future style of development of hybrid multiregional models is quite clearly eclectic. Theoretical notions and analytical techniques imported from other disciplines are likely to be integrated with the traditional arsenal of the economic geographer, regional scientist or the regional economist.

Fourth, the trend in future modeling in this area is quite clearly from linear modeling to systems, from specific frameworks to general relativistic frameworks.

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Appendix C

Essay on Data Quality, Model Complexity and Uncertainty

David Leinweber
The Rand Corporation

"It's very difficult to predict, especially the future." --Neils Bohr

Building and using a model entails a set of related activities. Input data must be collected, the model itself needs to be precisely specified and constructed, as well as a method interpreting the results. In engineering and the "hard" sciences this process can be fairly straightforward, but when the domain of the model is socio-political or economic or both, it is considerably more difficult.

The Data

The input information available to economic and policy modelers is not of a uniformly high quality. In 1950, Oskar Morgenstern discussed these problems in On the Accuracy of Economic Observations. He cited multiple sources of error, including the lack of designed experiments, deliberate hiding of information and lying, improperly trained observers, poorly designed questionnaires, lack of proper information definitions, measurement errors, and the inability to allow for unique or changing circumstances.

Things are not much better today. There is an unreported portion of the GNP that may amount to more than \$200 billion. This represents activity in the barter economy, off-the-books employment, drug traffic (which recently surpassed tourism as the largest industry in Florida), and other unsavory endeavors. Since \$200 billion is 10 percent of the total reported GNP, it seems fair to assume that the accuracy of much of the published information on inter-sector transfers and the like may be suffering as a consequence.

There are still ample reasons for deliberate data distortions. A notable example is DOE's multiple tier oil pricing system, which turns into cash for what is apparently a disturbingly large group of petroleum dealers.

Bureaucratic and institutional inertia often encourage shortcuts in meeting federal reporting requirements. It is much easier to use or adjust last year's numbers than to bother with actually going out and measuring what is supposed to be measured.

The list of possible problems with economic information is endless. Let it suffice to say that economics is not physics and never will be.

The Model

So we have all this rotten data. What does this imply about model design? The answer is found in Figure 1, which shows a series of graphs of model error versus model complexity. Figure 1a shows one kind of model error (the error of specification). This is the error in the model's prediction if it were working with perfectly accurate ideal data for inputs. The only legitimate reason for making a model more complex is to increase its accuracy. Complicating a model without an increase in accuracy is, in game-theoretic terms, an inadmissible strategy. This doesn't mean it doesn't happen, only that in an ideal world, it wouldn't. The downward curve of e_S , the error of model specification, reflects this idealized notion. Real models may be worse, but not better.

The second curve, in Figure 1b, shows e_M , (the compounded error of measurement) in a model. This is the error that arises from the unavoidable errors in real data that compound as more arithmetic operations are performed on them. As the models grow larger and more complex, the compounded error in the prediction increases.

Adding the two curves shown in Figures 1a and 1b produces the curve of total error, e_T , shown in Figure 1c. The important point is that this curve has a minimum. There is an optimal model complexity for attacking a problem based on real, i.e., imprecise data. Further complicating the model buys nothing. It does impose an additional cost in accuracy of predictions, as well as the cost of resources required for a more complex analysis.

An important point is made by considering what happens when the quality of the data gets worse. Figure 2a shows e_{M2} , the compounded error of measurement curve for a set of data worse in quality than was used in Figure 1. The original data from Figure 1 is shown on the same axes as e_{M1} .

Adding both e_{M2} and e_{M1} to e_S , the error of specification, produces two total error curves, e_{T1} , identical to that shown in Figure 1c, and e_{T2} , the total error for the poor data case. Notice that the minimum point on the

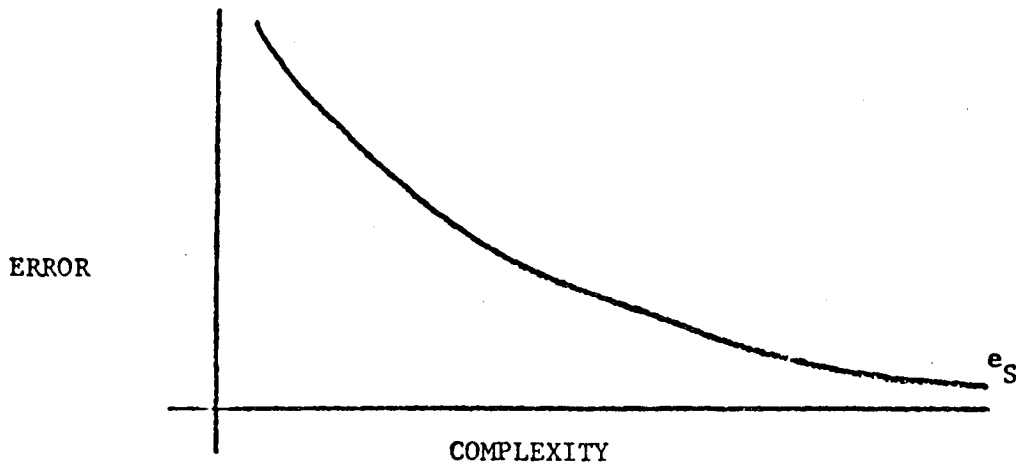


Figure 1a.
Error of
Specification

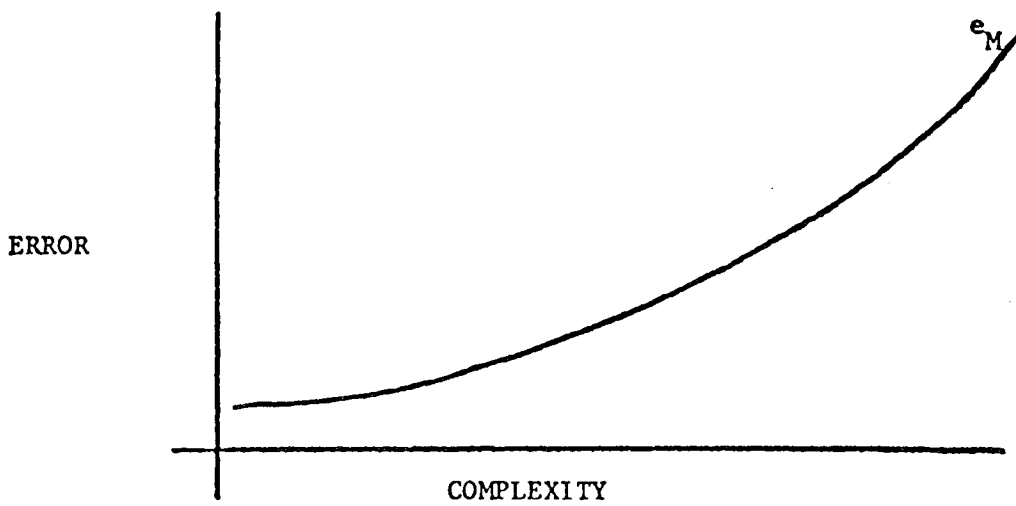


Figure 1b.
Compounded Error
of Measurement

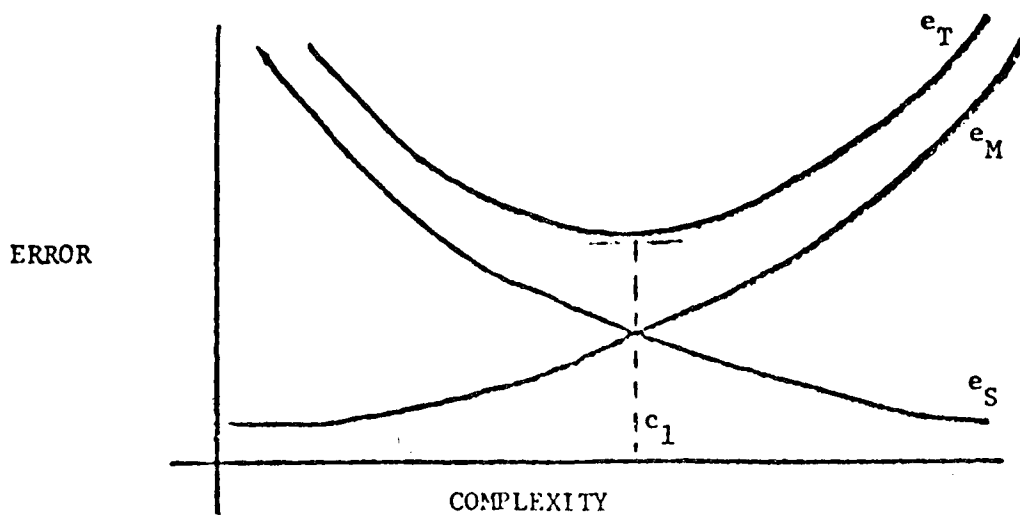


Figure 1c.
Total Error

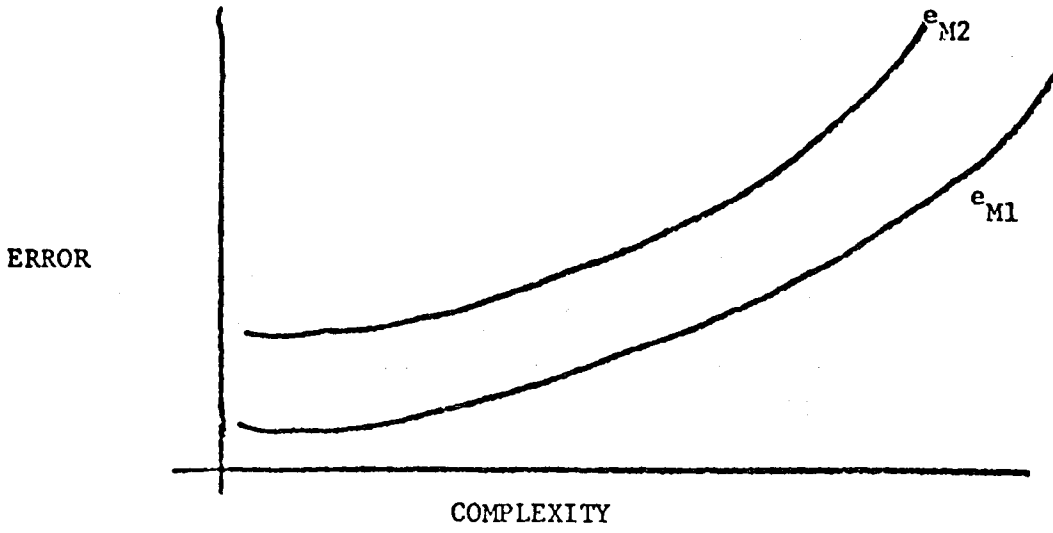


Figure 2a.
Compounded Errors
of Measurement

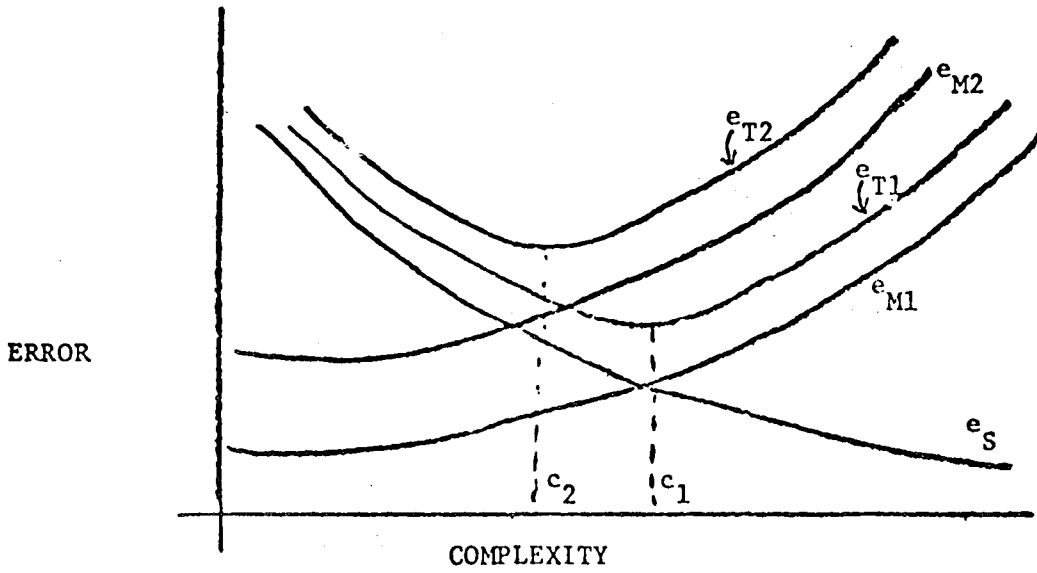


Figure 2b.
Total Errors

curve moves to the left. As the data gets worse in quality, the optimal level of model complexity decreases. Put more succinctly: Lousy data implies simpler models.

When this notion is taken to the limit, with the quality of the data becoming increasingly poor, the optimal complexity for the model using that data (denoted by C_2 in Figure 2b) approaches zero. A model of zero complexity is an intuitive guess. When the data are nonexistent or worthless, this is the best model available.

There is good evidence that many real models are more complex than they should be, given the quality of the data they run on. Much of the detail in models is based on presumed detail in the data which, on closer inspection, is not really there. An overly detailed and complex model may be well past the point of diminishing information returns with regard to the domain under investigation.

The Application

It should go without saying that a model should be appropriate to its application. For new models, this should be fairly well assured; for existing models, it is not so certain. (There is a great temptation to apply models in areas beyond their intended range, to ask questions about issues to which the model is essentially blind.) The situation is worst in the case of large, expensive, complex models that represent a substantial investment by the sponsors. This kind of institutional momentum leads to the development of a myriad of add-on modules, adjustment factors, complex feedback systems and other contrivances which add little or no value to the information derived from the model. This situation is the logically inadmissible strategy referred to previously, in which the complexity of the model increases without a reduction in the error of specification.

The Results

What happens after the data has been collected and the model designed, implemented, and applied to the problem? The issue becomes one of deciding on how to interpret the results.

The model's predictions are in the form of numbers, which, hopefully, in some way describe what the future will be. Placing a lot of credence in the absolute level of the prediction, the value itself, can be a risky proposition, especially for times more than five or ten years into the future.

The Energy Modeling Forum at Stanford University applied a group of coal models to a standardized problem and came up with a remarkably broad set of predictions. The curves from the different models tended to move together, but the absolute values of the predictions varied widely (see Figure 3). The implication is that it may be better to interpret the results of modeling analyses in a differential mode, i.e., to look at the change in the predictions for one case relative to another. In policy analysis, this is often the kind of question one is interested in anyway. If there are two or more alternative actions under consideration, the basis for a differential comparison clearly already exists. For most problems, a base case or business-as-usual scenario can be constructed to provide a reference point for the differential comparisons. The use of this technique is shown in Figure 4, a map showing estimated 1985 sulfur oxide emissions under the original Carter energy plan relative to estimated emissions if the plan were not in effect.

Differential mode interpretation is probably the safest way of looking at model results in use today, but there is still room for improvement. There are uncertainties and errors in the model's results, as well as in its inputs. They are somewhat more difficult to quantify, since it is a fairly intractable mathematical procedure to trace changes in the distribution of the input variables as they churn through any (but the simplest) model and become output variables. If this could be done, one could then interpret the results in a differential probabilistic sense, and obtain measures of the statistical validity of one's results, along with the results themselves. Generating and convolving the distributions of predictions or approximations of these distributions allows the modeler to distinguish between a real statistically significant effect and one that is just random noise.

The map in Figure 4 corresponds (partially) to the request: "Show me those regions which will experience an increase greater than 10 percent in sulfur oxide emissions." A probabilistic differential map would correspond to requests similar to: "Show those regions which will experience an increase greater than 10 percent in sulfur oxide emissions, with a statistical likelihood of at least 80 percent." For a complex model, it is essentially impossible to do this precisely, but it can be done in an approximate way. If reasonable assumptions are made concerning the accuracy of components

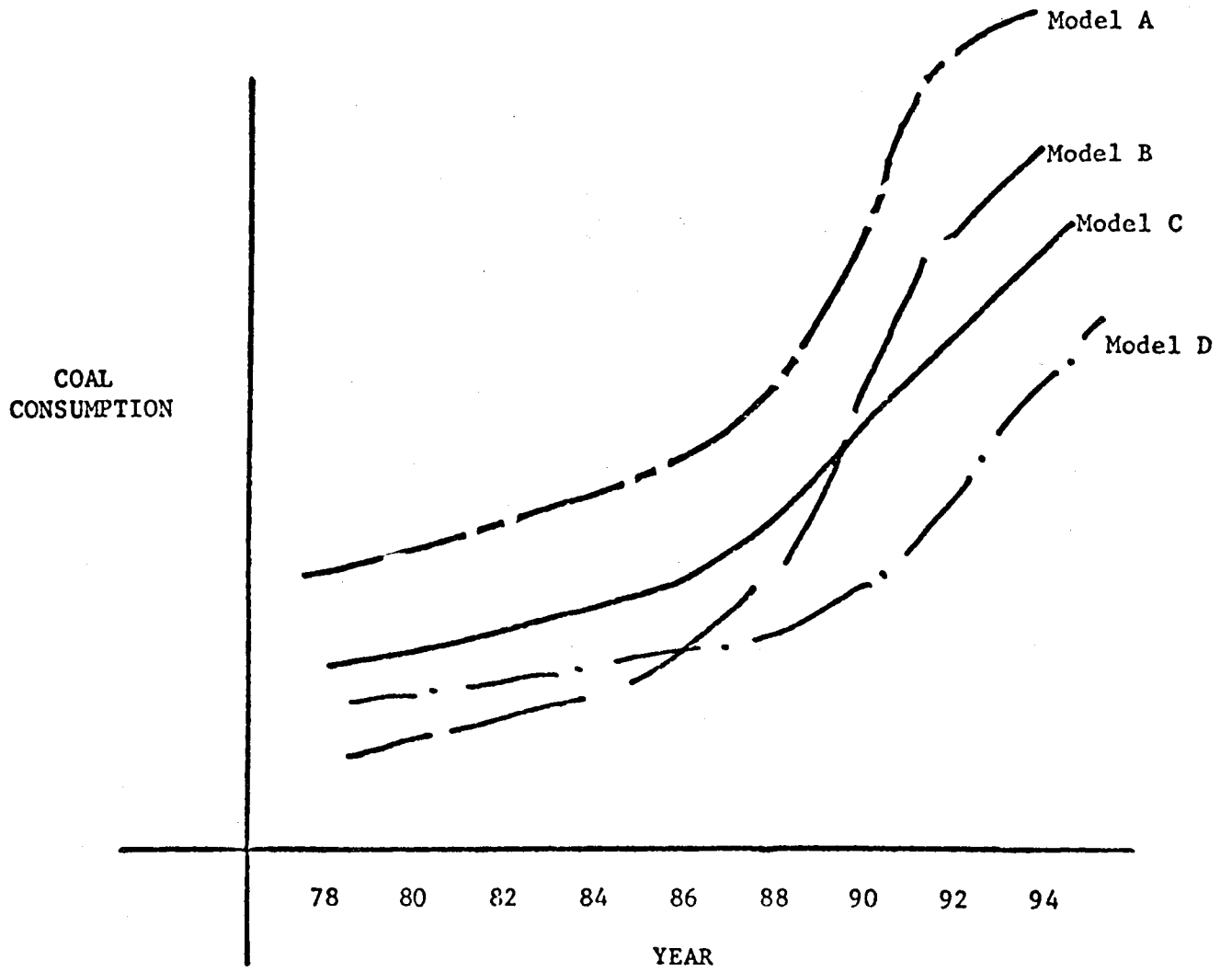


Figure 3. Results of Study Comparing Coal Models Using Identical Inputs

1985 INITIATIVE SOX BY AQCR

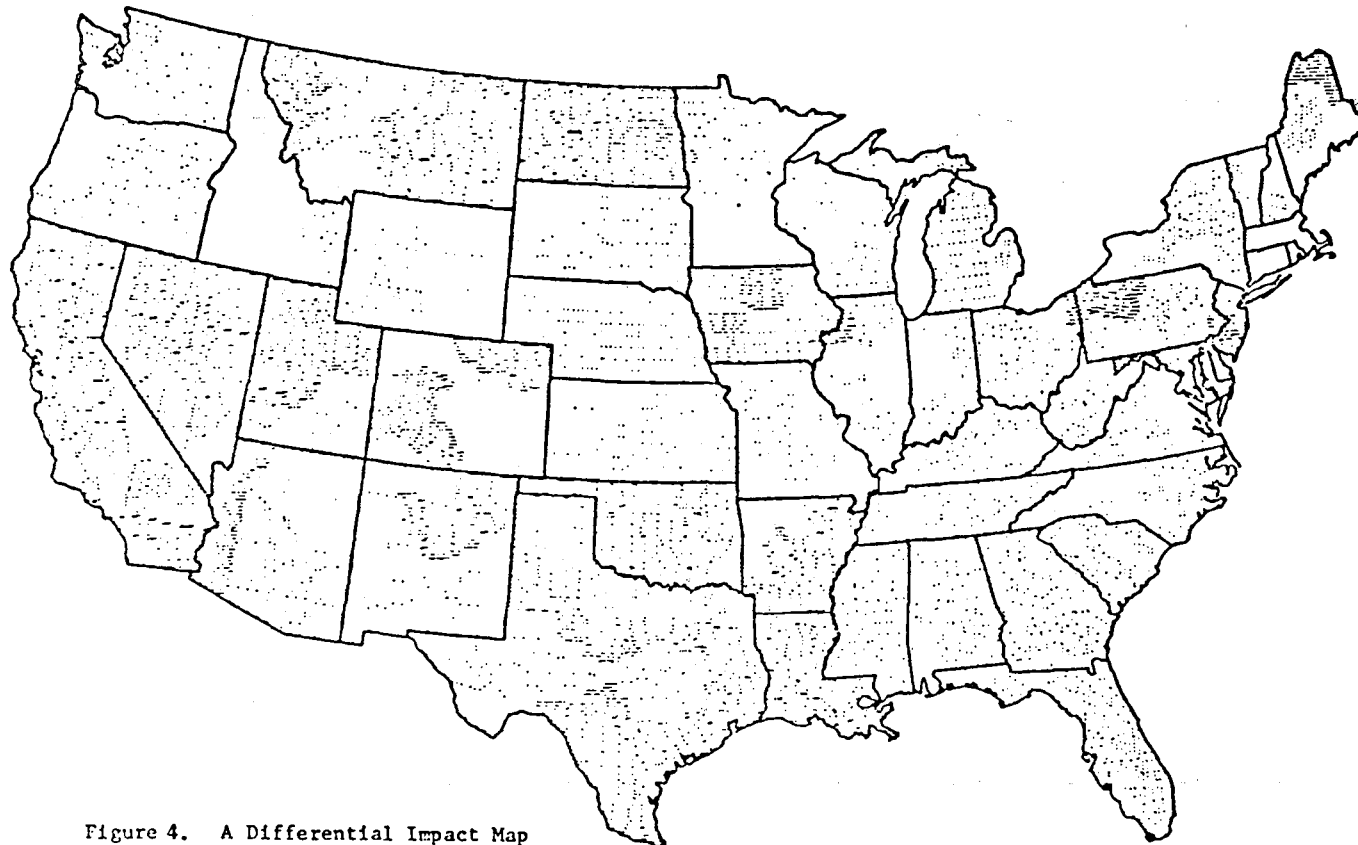


Figure 4. A Differential Impact Map

PERCENT OF 1985 NOMINAL

☐ ABOVE 110

☐ 90 TO 110

☐ 0 TO 90

of the model's final results or if actual data on the accuracy of some components are known, it is usually possible to envision a practical way to combine the known and assumed uncertainties to produce some kind of approximation to the distribution of predictions, and to convolve these distributions, yielding an approximate probabilistic differential result. Some of this must be done on an ad hoc basis; it may be best to use a range of assumptions concerning the uncertainties in the models, ranging from very optimistic to very pessimistic, and see how this affects the confidence intervals for the results. If you have to make heroic assumptions everywhere before anything significant beyond the 10 percent level appears, it is likely that your model is not really telling you very much. If 70 percent likelihoods are seen in the results with moderate assumptions you may well be observing a real effect.

Important policy decisions should not be based on noise. While it is far from clear that such decisions actually are closely coupled to modeling, it is worthwhile to make some attempt to determine the validity of one's conclusions, whatever their ultimate application may be.

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