

CHAPTER 1

Overview

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The last 15 years have witnessed a growing international effort to increase understanding and broaden public awareness of the conditions, problems, and opportunities that are likely to confront the world through the end of this century and into the more distant future. This ongoing “futures debate” has been stimulated in part by the publication of a series of long-range forecasts of global trends in population growth, resource availability, economic development, and environmental conditions. Many of these forecasts have been based on the findings of “global models” —computerized mathematical simulations of the world’s physical, economic, and political systems. As tools of strategic analysis, these models have been used to study the interactions and future implications of past events and current trends. As tools of policy formulation, global models have been used to evaluate or promote alternative actions and programs

that might bring about different or more favorable world futures.

This report surveys the assumptions, findings, and recommendations of five major global modeling studies (see table 1). It also considers the use of global models within the U.S. Government, such as the World Integrated Model (WIM) that is being used by the U.S. Joint Chiefs of Staff (see pp. 23-24). In addition, the report presents strategies that have been suggested for improving the quality and relevance of the Government’s modeling capability. Of great interest in this connection is the newly created White House “national indicators system” (see p. 65). The appendixes provide detailed comparative analyses of the models’ projections of population, agriculture, and energy trends.

Table 1.—Summary Description of the Five Global Modeling Studies Discussed in This Report

Model	Historical Date base period	Projection time horizon	Geographical regions	Alternative scenarios
World 3	1972 1900-1970	2100	1 (global)	11
World Integrated Model (WIM).	1974 1950-1975	2025	10 (later 14)	17
Latin American World Model (LAWM).	1976 1960-1970	2060	4 (later 15)	7
United Nations Input-Output World Model (UNIOWM)	1977 1970 ^b	2000	15 (3 blocs)	13
Global 2000	1980 Not consistent	2000	5 to 28 (Not consistent)	12

^aNumber of computer runs, sensitivity tests, or policy scenarios examined by Office of Technology Assessment in the text of appendixes of this report
^bSystem structure and behavior in 1970 were verified through comparison with cross-sectional data dating back to 1955 or 1960.

SOURCE: Office of Technology Assessment.

Findings of the Global Models

Global modeling studies have varied widely in their purposes, techniques, findings, and prescriptions. The results of some studies have been guardedly optimistic, while others have been highly pessimistic. Their specific quantitative results have been different because they have made different assumptions and have focused in different ways on different parts of the global system. Nevertheless, they have generally iden-

tified the same problems and seem to have arrived at roughly similar qualitative conclusions about the present state of the world and its plausible futures:

- Population and physical capital cannot grow indefinitely on a finite planet without eventually causing widespread hunger and resource scarcities. However, there is no physical or

technical reason why basic human needs could not be supplied to all the world's people, now and for the foreseeable future. These needs are not now being met because of unequal distribution of resources and consumption—not overall physical scarcities. The absence of physical limits, however, does not necessarily imply the existence of a practical solution.

- The continuation of current trends would result in growing environmental, economic, and political difficulties. As a result, “business as usual” is not a palatable future course. Technological progress is expected (and in fact essential), but no set of purely technical changes tested in the models was sufficient in itself to bring about a completely satisfactory outcome. The models suggest that social, economic, and political changes will also be necessary.
- Over the next two or three decades, the world's socioeconomic system will be in a period of transition to a state that will be significantly different from the present. However, the shape of this future state is not predetermined—it is a function of decisions and changes being made now.
- Because of the complexity, momentum, and interdependency inherent in the world's physical and socioeconomic systems, the full long-term effects of a given action are almost impossible to predict with precision or certainty. However, actions taken soon are likely to be more effective and less costly than the same set of actions taken later, and cooperative long-term approaches are likely to be more

beneficial for all parties than competitive short-term approaches.

- Many existing plans and agreements—particularly complex, long-term international development programs—are based on assumptions about the world that are either mutually inconsistent or inconsistent with physical reality.
- Pollution and resource availability may or may not be problems on a global “scale,” but there is general agreement that regional problems of global concern—such as food shortages in South Asia and perhaps Sub-Saharan Africa—are far more likely than a global collapse.

In some cases individual global models have been used to support more dramatic conclusions and more specific prescriptions than these, but it would be a mistake to confuse global modeling as a method of analysis with any particular prediction or recommendation. As a tool of analysis, global modeling is in itself neutral, although like any complex tool a given model can be designed or used inappropriately. For instance, most global models contain little or no representation of geopolitics; it would thus be inappropriate to use them to predict short-term events that may in fact be more strongly affected by nonquantifiable political variables. Similarly, the findings that come out of a model will also depend on the data and assumptions that go into it, the purposes to which it is put, and the way it is interpreted. As a result, global modeling can be a useful technique in long-range analysis, but it should not be—nor is it likely to become—the sole, or even the principal, basis for decisionmaking.

Global Modeling and Government Foresight

Global modeling is used by a variety of organizations and is by no means the exclusive preserve of environmentalists or those who advocate a “new international economic order.” A growing number of large domestic and multinational corporations routinely employ the projections of private economic modeling services in their corporate planning. Several foreign governments and inter-

national organizations support ongoing global modeling programs, and a variety of models—global and otherwise—are also in use throughout the U.S. Government in a wide range of forecasting applications. The Joint Chiefs of Staff, for example, are developing a version of WIM for use in their joint long-range strategic appraisal, and both the Department of Agriculture and Bureau of

Mines have used WIM as well as other models. The Global 2000 Study found that numerous Federal agencies (including the Central Intelligence Agency and Department of Energy, as well as the Agency for International Development, Bureau of the Census, and Environmental Protection Agency) routinely use regional or sectoral models in carrying out their long-range analysis and planning functions. Similarly, the Members and committees of Congress have access to long-term econometric models maintained by the Congressional Budget Office (as well as the findings of models maintained by the executive agencies) for use in their oversight, assessment, and legislative functions. This Government modeling capability exists because it is necessary, and it has shown itself to be useful over the years.

The expanded and better coordinated use of global models could offer the U.S. Government an opportunity to improve its existing foresight capability. "Foresight" relates to the ability to effectively address long-range issues by first anticipating future developments, and then formulating policies and programs that will minimize potential problems or exploit potential opportunities. Although global models cannot generate precise, detailed predictions of what will happen in the future, they can be used to produce conditional forecasts of what is likely to happen or the probabil-

ity of different outcomes, given certain specific assumptions about trends, policies, and events. They can also be used to test the consistency of assumptions and predicted outcomes for different policy options. In addition, the models can generate order-of-magnitude estimates of many demographic, economic, and resource factors at the global, regional, and national levels.

This level of forecast accuracy and detail can be useful for a wide range of applications in long-range assessment and policy-development activities. Deficiencies do exist in the Government's current capability, but if these deficiencies are corrected global models could become a more effective input to policymaking in four specific areas:

- assessing the future impacts of current trends and existing policies;
- monitoring the national and international situation to identify early signs of potential problems or opportunities;
- formulating and testing a wide range of alternative policies and courses of action for achieving national goals, avoiding potential problems, and exploiting potential opportunities; and
- providing a framework to ensure consistency between short- and long-term analyses and across agency jurisdictions.

Strengths and Weaknesses of Global Models

Global models offer a number of methodological advantages over traditional techniques of long-range analysis and policy development:

- **Longer time horizon.** -Traditional methods are used primarily for annual or short-term forecasts, whereas global models typically have horizons of 20 years or more. This allows global models to assess long-term effects and cumulative changes that might not otherwise be anticipated.
- **Comprehensiveness.** —The computer can contain far more information about a system or process than any single mental or verbal model, and it can keep track of far more interrelations and variables at the same time. Global

models can therefore enable the analyst to utilize substantially more information, and do so more meaningfully (e.g., with regional disaggregation) than could otherwise be done.

- **Rigor and accessibility.** -Modeling requires explicit, precise, and complete statements of objectives, assumptions, and procedures. These must be written out before they can be run on the computer, and this makes it easier for all sides to examine them and point out omissions and inconsistencies. Open communication about the system and the model can lead to revisions and refinements even before analysis begins, and it can also contribute to the dialog through which clear-cut goals are established.

- **Logic.**—The computer can draw logically correct and mathematically error-free conclusions from an extremely complicated set of assumptions and data. This can lead to insights into unexpected or counterintuitive system behavior, reveal areas in which further research is needed, and expose assumptions and objectives that are inconsistent, contradictory, or physically impossible.
- **Flexibility.**—It is possible to tailor global models to fit particular problems or regions. By changing the magnitude of specific variables and relations, global models can also be used to test a wide range of assumptions and policy alternatives. This can make the global model a valuable tool for policy formulation, as well as a device with which planners and policy makers alike can sharpen their analytic skills and improve their intuitive “feel” for the probable behavior of global systems.

Global models are, however, subject to a number of limitations that can constrain their accuracy, reliability, and usefulness:

- **Methodological constraints.**—The essence of modeling is a simplification that improves understanding, but this means that a limited

set of discrete factors and relations are used to describe the complexity and ambiguity of the real world. There is little agreement, however, on the proper level of complexity or integration. Similarly, there are no generally accepted tests of model realism, making quality control and third-party validation important considerations.

- **Theoretical constraints.**—Current understanding of some causal relationships is far from adequate, particularly for environmental and sociopolitical processes, and this too can lead to inaccurate or invalid assumptions. As a result, the theoretical biases of the modelers or the specific needs and assumptions of model users—can sometimes lead to oversimplification or distortion.
- **Data constraints.**—In many areas there is a lack of adequate, reliable, and consistent data. This, too, can be a source of forecast error, as well as a constraint on the issues or regions to which global models can be reliably applied.

Because of these limitations, it is vital to evaluate the assumptions and uncertainties underlying the forecasts, if the results are to be understood and used by policy makers.

Institutional Barriers

Several assessments of the Government’s modeling capability have concluded that the institutional context in which models are currently used is as much of a constraint on their usefulness as the above technical limitations. Frequently cited institutional barriers include the following:

- poor communication between modelers and potential model users, resulting in projections that are unresponsive to the information needs of policy makers;
- narrow specialization of interests and responsibilities, at the expense of interactions among

sectors and cooperation among agencies, complicated by inadequate mechanisms for transferring data and resolving problems between agencies;

- lack of understanding, confidence, or support for modeling among top-level policy makers, resulting in a failure to integrate forecasting and policymaking activities; and
- lack of interest in long-term global issues on the part of the Federal agencies, Congress, and the general public.

Strengthening the Government's Modeling Capability

Proposals for improving the Government's modeling capabilities usually stress the need for a coordinated strategy involving complementary efforts at all levels. The proposed initiatives generally reflect four fundamental priorities:

- **Correct existing deficiencies.**—Relevant agencies might create internal advisory committees to:
 - 1) prepare an inventory of existing models, their uses, their deficiencies, and any planned modifications;
 - 2) conduct a survey of current or potential applications by analysts and policymakers, with particular attention to their specific information needs;
 - 3) evaluate existing data bases to determine data needs and possible ways of gathering data that are scarce; and
 - 4) improve communication between policymakers and modelers in order to increase the relevance and responsiveness of forecasts.
- **Coordinate existing capabilities and activities.**—Some form of interagency mechanism might be established in order to:
 - 1) identify areas of compatibility and sources of inconsistency among models;
 - 2) promote communication and technical cooperation among agencies;
 - 3) develop consistent standards and protocols for the reliability, validation, and documentation of both models and data;
 - 4) provide a clearinghouse for easier access, exchange, and integration of other agencies' data, assumptions, and projections; and
 - 5) resolve problems among agencies through negotiation or arbitration.
- **Support technical improvements in the Government's capability and the state of the art.**—An independent or "quasi-public" institute might be created to promote research on global modeling and futures research. Its specific functions might be to:
 - 1) encourage impartial, third-party validation and assessment of existing models;
 - 2) support nongovernmental research on global models and establish a "global modeling forum" (analogous to the Energy Modeling Forum at Stanford University) at which modelers could exchange ideas and critique one another's work;
 - 3) enlist the talents and participation of the private sector in Government foresight activities; and
 - 4) assess modeling work done outside the United States and maintain communication with international organizations such as U.N. agencies and the International Institute of Applied Systems Analysis.
- **Link foresight with Policymaking.** -To ensure that long-range global issues are routinely taken into consideration in the formulation and implementation of U.S. policy, Congress may wish to coordinate and upgrade the foresight capabilities of its legislative research agencies and/or authorize the creation of a new unit in the Executive Office of the President. The functions of this new unit might be to:
 - 1) supervise and/or coordinate the strategies outlined above;
 - 2) provide the President and other top-level decisionmakers with thorough analyses and a broad range of policy options on global issues;
 - 3) evaluate the long-term effects of agency goals and budget items on global trends and U.S. strategic interests, for consideration by the Office of Management and Budget and Congress in the budgetary process;
 - 4) prepare a "policy statement on the future" to be delivered by the President;
 - 5) issue periodic reports on specific global issues;
 - 6) conduct comprehensive, integrated studies of long-range trends and problems at regular intervals; and
 - 7) in conjunction with the Department of State, encourage foreign national assessments of long-range issues and support the data-gathering, analytic, and problem-solving activities of the United Nations, international financial institutions, and nongovernmental organizations.

Conclusions

1. Global modeling represents an important analytic tool for exploring alternative world futures and for testing the feasibility and long-term effects of alternative policy actions.
2. The current state of the art in global modeling offers the U.S. Government a significant opportunity to improve its foresight capability, if the models are used judiciously and in combination with other techniques and inputs to strategic analysis and policy development.
3. If models are to be used properly within their present limitations, it is critical to: 1) determine and state explicitly the purposes, assumptions, and theoretical biases of the model; 2) ascertain the extent of uncertainty in a particular projection and its sensitivity to changes in the underlying assumptions; and 3) differentiate between descriptive forecasts and those that are prescriptive or normative.
4. Improvements in socioeconomic theory, modeling methodology, and data-gathering technologies could substantially improve the usefulness of the projections generated by global models.
5. Existing deficiencies in the Government's modeling capability are institutional as well as technical in nature, and any effort to correct these deficiencies will require better coordination among Federal agencies and increased attention to the information needs of policymakers and decisionmakers.