CHAPTER 2

Major Global Modeling Studies

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Introduction

Forecasts and Forecasting

Formal forecasting, which appeared in the early 20th century, is based on the rigorous application of empirical inquiry and statistical analysis to the prediction of socioeconomic change. It insists on careful monitoring, a firm data base, and the judicious use of trend extrapolation, while rejecting unfounded optimism and utopianism as "wishful thinking." The first use of formal forecasting by the U.S. Government came in 1929, when President Hoover created a Presidential Research Committee on Social Trends, and its techniques and findings became linked with comprehensive planning and decisionmaking during the New Deal. Further theoretical improvements and practical applications have emerged since World War 11 through developments in econometrics, general systems theory, cybernetics, operations research, and input-output analysis.[1]

For strategic analysis and policymaking purposes, three general types of forecasts can be distinguished, based on their approach to foreseeing the future:[2]

- unconditional forecasts, which determine that certain events or trends will, in all probability, occur in the future (these forecasts might properly be called "predictions");
- conditional or probabilistic forecasts which determine that certain events or trends are more or less likely to occur in the future, given certain limiting assumptions concerning present and future conditions and policy actions (and that, given a different set of assumptions, different events or trends are more or less likely to occur); and
- exploratory forecasts, which examine a wider range of policies and trends in an open-ended exploration of possible future developments, with less emphasis on the plausibility of assumptions or scenarios.

To these three types of descriptive forecasts, which attempt to project what will or might happen in the future, a fourth could be added:

- prescriptive or normative forecasts, which identify events or trends that should (or should not) happen and determine the policies and conditions that will promote the desired outcome.

Models and Modeling

A model is a simplified or generalized representation of something else—an object, process, or system. The model need not resemble the original and can in fact take many forms, depending on the purpose it is to serve: as an aid to memory, a small two-dimensional photograph can remind us of a large three-dimensional person or place we have seen; as an aid to discocery, a 3-lb model airplane can be tested in a wind tunnel to predict the performance of a 30-ton airliner built on the same design; and as an aid to explanation, a set of gravitational equations can be used to elucidate the intricate motion of planets orbiting a sun.

The model need not depict every detail of the thing it represents. A good model reduces the complexity of the original by eliminating elements and relations that are irrelevant to the purpose at hand, retaining only the characteristics that are needed for that purpose. Ingeniously simple models may be described as "elegant, " but in the end "a model can be made and judged only with respect to a clear purpose."[3]

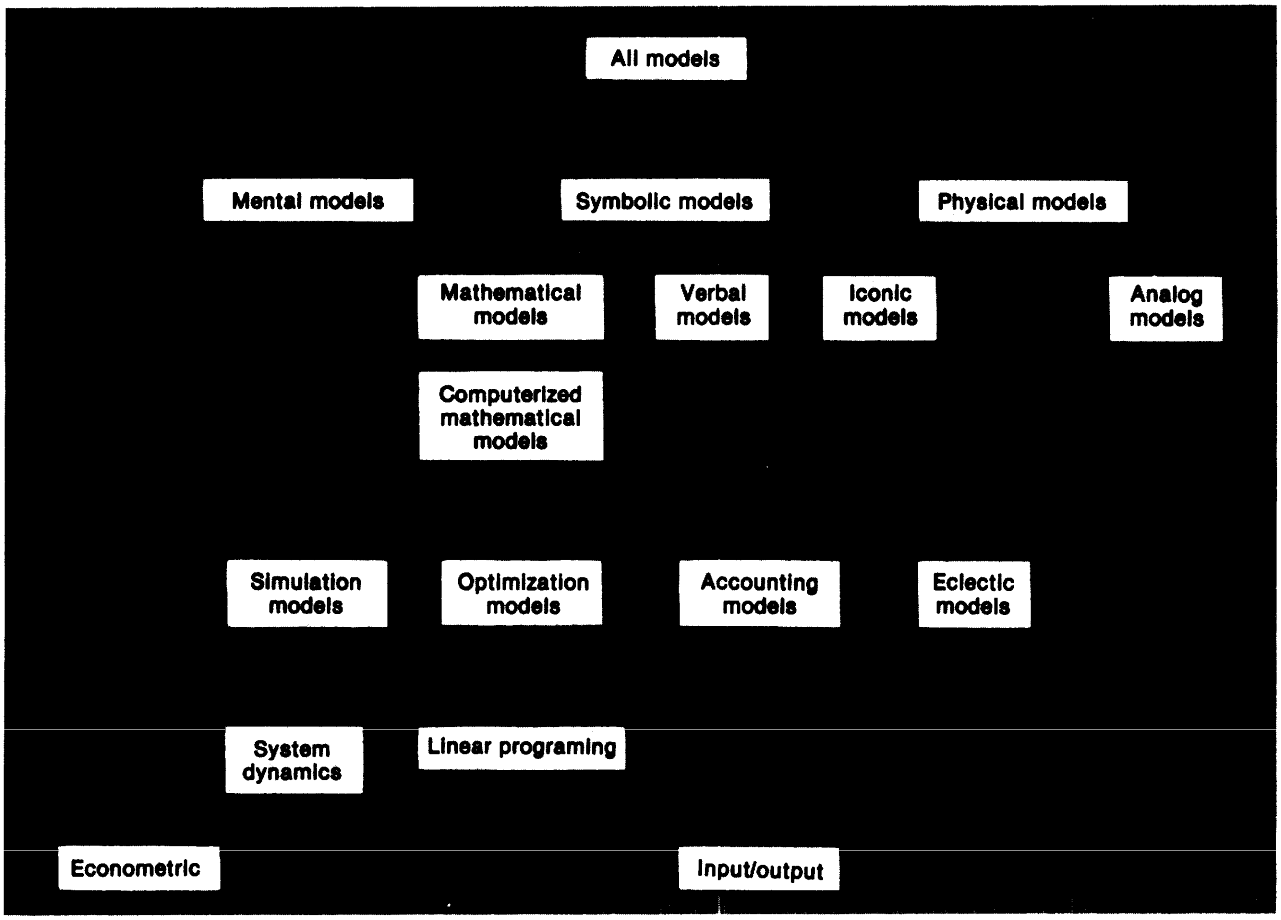
Models can be divided into three basic types: mental models, physical models, and symbolic models (see fig. 1). Mental models are the concep-

[1] Dennis L. Little, et al., *Long-Range Planning* (Washington, D.C.: U.S. Library of Congress Congressional Research Service, 1976), prepared for the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology, pp. 384-390.

[2] Arthur D. Little, Inc., *Long-Range Forecasting Models of Population, Natural Resources, and the Environment: Their Use in Foreign Policy Assessments at the National Level* (prepared for the U.S. Department of State, Nov. 1979), pp. II.2-3.

[3] Donella H., Meadows, John Richardson, and Gerhart Bruckmann (eds.), *Groping in the Dark The First Decade of Global Modeling* (New York Wiley, forthcoming), pp 37-38; emphasis theirs.

Figure I.—Types of Models



SOURCE: Arthur D. Little, Inc.

tual models people carry about in their heads and use to think about the world. They are flexible, adaptable, creative, and contain rich stores of information about such intangible factors as values and motivations. Some mental models are extremely subtle and elaborate, even elegant. But they can also be vague, shifting, unverbalized, and immune to objective criticism, and they are often based on dubious but strongly held assumptions. Judgmental and qualitative forecasts (including many unconditional forecasts) are often based on mental models.[4]

Physical models are created from tangible materials, and the process of embodying the model can usually make it both more explicit and more open to objective criticism. Iconic or schematic models, such as maps or diagrams, are physically similar to their originals, although they may not behave in the same manner. Analog models, such as wind tunnels, reproduce the behavior of their originals without necessarily resembling them in appearances Physical models can be a useful means of communicating, clarifying, and correcting mental models.

Symbolic models make use of some system or language of symbols to describe the relevant elements and relations of the object, process, or system they represent. Verbal models, such as Das Kapital or Wealth and Poverty, take the form of oral or written language. As a result, they can be more

[4]Ibid., pp. 20-21, 37-38; and Arthur D. Little, Inc., op. cit., p. II.6.

‘Arthur D. Lttle, Inc., op. ctt., p. 11.6.

explicit and precise than mental models, but at the same time they are potentially diffuse, impressionistic, ambiguous, and rhetoric al. Mathematical models, on the other hand, can represent the relevant elements and relations of a real object, process, or system in mathematical symbols and equations. This allows them to express complex operations concisely, precisely, and explicitly in a rigorous and consistent language. This in turn makes them more open to objective criticism and correction, but mathematical models remain susceptible to omissions, distortions, and misinterpretations like those that afflict mental and verbal models. They can be no more valid or reliable than the theoretical understanding on which they are based and the mathematical form in which they are expressed.

Computerized models are mathematical models that have been rewritten in a programing language that can be run on a computer. They can be used to investigate a process, system, or theory that is too large or too complicated to model adequately (or manipulate conveniently) in words or a few simple equations.[6] Such models can contain more elements (variables), more relations (equations), and far more empirical data than simpler models. The computer can keep track of all of these factors simultaneously, manipulate them very rapidly, and produce results that are free from computational error. However, human judgment is still required to determine what factors to include, hem' to represent them, what data to use, and how to interpret the numerical findings. Consequently, the results that come out of the computer are only as reliable as the general assumptions, structural decisions, and data that go into it, and even the best results are subject to biased or mistaken interpretations.

Global models are simply computerized mathematical models whose purpose is to investigate systems, theories, and issues of a global scale and complexity, usually with a relatively long time horizon:

> Global modeling is distinguishable from other types of modeling of social systems only by the questions it asks. Its methods, strengths, and weaknesses are identical to those of all policy-oriented computer models. It draws from the same base of theory and data. Therefore, if there are any distinct properties of global modeling, they follow directly from the characteristics of global problems.[7]

The following survey will therefore focus not only on the modeling techniques that have been used and the findings that have resulted, but also on the global problems that have been addressed in the models and the purposes to which their findings have been put.

[6] Meadows, Richardson, and Bruckmann, op cit., p 20

[7] Ibid., p45

The Trend Away From Technological Optimism

Until about 1970, most long-range forecasts were characterized by generalized optimism about the benefits of continued economic growth and confidence in the ability of technology to overcome any barriers. The most influential of the forecasts was The Year 2000, by Herman Kahn and Anthony Wiener of the Hudson Institute, which offered a set of alternative "scenarios" as a "framework for speculation" on the future. Its central finding was "that economic trends will proceed more or less smoothly through the next thirty years and beyond," and that "we are entering a period of general political and economic stability at least so far as the frontiers and economies of most of the old nations are concerned."[8] This "surprise-free" scenario was based on exponential extrapolations of postwar demographic and economic trends, but it was also influenced by the authors' underlying assumption of "continuity" in global affairs, particularly the increased rate of technological innovation, and by their confidence that society would be able to find "physically nonharmful methods of over-indulging."[9] Kahn and

[8] Herman Kahn and Anthony Wiener, *The Year 2000: A Framework for Speculation on the Next Thirty-three Years* (New York: Morrow, 1967), pp. 116-128; emphasis added.

[9] Ibid., pp. 6, 122, 52.

Wiener do caution that "increasing discrepancies between rich and poor" could lead to resentment and instability, and that the "problems of development constitute a serious economic and moral concern."[10] Nevertheless, according to one critic, "they simply refuse to be overawed by the magnitude of the problems posed."[11] Although sharply criticized in recent years, this view of the future has remained influential in both Government and corporate policy, as well as public opinion, in the United States.[12]

Since the late 1960's–and particularly since the 1973 oil embargo–a less optimistic view of the future has gained currency, a view characterized by increased concern for the feasibility and environmental consequences of unrestrained economic growth and by criticism of the social and political institutions that have supported such growth, This new mood, which has been characterized as "neo-Malthusian pessimism," was influenced in part by the projections of economist Joseph Spengler and by the popular success of several books by Anne and Paul Ehrlich, who argued that the world is already over-populated and overdeveloped in terms of its ecological resources.[13] By far the largest stimulus to public debate over these issues came from the activities of the Club of Rome (an international group of businessmen, academics, and civil servants) that was organized in 1968 by Italian management consultant Aurelio Peccei,

The Club of Rome's "Project on the Predicament of Mankind" focuses on the complex interacting socioeconomic problems that make up the so-called "world problematique:"[14]

- poverty in the midst of plenty;
- degradation of the environment;
- loss of faith in institutions;
- unconrtolled urban spread;
- insecurity of employment;
- alienation of youth;
- rejection of traditional values; and
- inflation and other monetary and economic disruptions.

The predicament of mankind, according to the Club, is to be able to perceive this problematique but to be unable to understand its origins or operation and, therefore, unable to respond to it effectivelv.

The Club's continuing program, consequently, has two objectives: 1) to gain a better understanding of the limits of the world system, the interaction of its dominant elements, and the constraints it puts on human numbers and activities;[15] and 2) to encourage appropriate sociopolitical reforms by bringing the world problematique to the attention of the general public and (more pointedly) the world's leaders and decisionmakers. The Club "hit on the idea of using a computer to advertise their cause," as one critic puts it, not only because "the field of Systems Dynamics had created a body of expertise uniquely suited to the research demands," but also because the resulting report might prove to be "a vehicle to move the hearts and minds of men out of their ingrained habits."[16] These dual purposes led to the first true global model, which also remains the best known and the most controversial.

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[10] Ibid., pp. 142, 364.

[11] Sam Cole, "The Global Futures Debate 1965-1976," in *World Futures: The Great Debate*, Christopher Freeman and Marie Jahoda (eds.) (New York: Universe Books, 1978), p. 23.

[12] M. Marien, "Herman Kahn's 'Things to Come,'" *Futurist*, February 1973, p. 7; cited by Cole, op. cit., p. 23.

[13] Cole, op. cit., p. 27; see also Joseph Spengler, "The Economist and the Population Question," *American Economic Review*, December 1966, and *Population Change, Modernization and Welfare* (Englewood Cliffs, N.J.: Prentice-Hall, 1974); see also Paul R. Ehrlich, *The Population Bomb* (New York: Ballantine Books, 1968), and Anne and Paul R. Ehrlich, *Population, Resources, Environment: Issues in Human Ecology* (San Francisco: Freeman, 1970).

[14] William Watts (President, Potomac Associates), "Foreward," in *The Limits to Growth*, by Dennis L. Meadows, et al. (New York: Universe Books, 1972), pp. 10-11.

[15] Aurelio Peccei, et al., "Commentary," in *The Limits to Growth*, p. 185.

[16] Cole, op. cit., pp. 28-29; and Watts, op. cit., p. 11.

World 3—The Limits to Growth

Origin and Purpose

In June 1970, when the Club of Rome was seeking a suitable methodology for their investimation of the global system, Jay For-rester of the Massachusetts Institute of Technology (MIT) invited the group to Cambridge for a demonstration of the capabilities of systems dynamics. Within 3 weeks he designed and documented a simple global model - World l - as the basis for presentations and discussions at the end of July 1970. (A revised version, World 2, was the subject of Forrester's subsequent World Dynamics (197l).) Impressed, the Club obtained a $250,000 grant from the Volkswagen Foundation to fund For-rester's colleague Dennis Meadow's and a team from MIT in developing a full-scale model—World 3—based on the systems dynamics approach. Under the auspices and direction of the Club of Rome, the MIT team produced both an elaborated model and a popularized presentation of it in less than 2 years—perhaps too quickly, in the view of one critic:

> The Club only relinquished control then the exercise had produced their desired product, as evidenced by the fact that client pressure drove the modelers to violate their scientific values by publishing The Limits of Growth beforc the technical documentation for World 3 was completed.

Structure and Assumptions

The World 3 model describes the global system in terms of five interacting subsystems—population, natural resources, capital, agriculture, and pollution-which are averaged on a global basis. Its most important conceptual contribution is the incorporation of "feedback" relations between these variables; due to these relations, attempts to solve one problem may unintentionally exacerbate another. The model also introduced the concept of "carry--ing capacity "—the level of population and production that could be sustained indefinitely by the prevailing physical, political, and biological systems of the world-and posited four possible "behavior modes" that a growing population could exhibit with regard to this carrying capacity (see fig. 2). None of these behavior modes reflects the potential ability of technology to expand the carrying capacity, primarily because the model assumes nonsubstitutibility between technology and resources.

The purposes of the model, according to the authors, were "to determine which of [these] behavior modes . . . is most characteristic of the globe's population and material outputs under different conditions and to identify the future policies that may lead to a stable rather than an unstable behavior mode,"[18] According to one critic, however, given the authors' "specific motivating concern with limits, the broad conclusions that emerged from the model are, perhaps, not surprising"—they assumed that limits exist and would eventually be reached; "[the] question was when and how."[19]

Findings of World 3

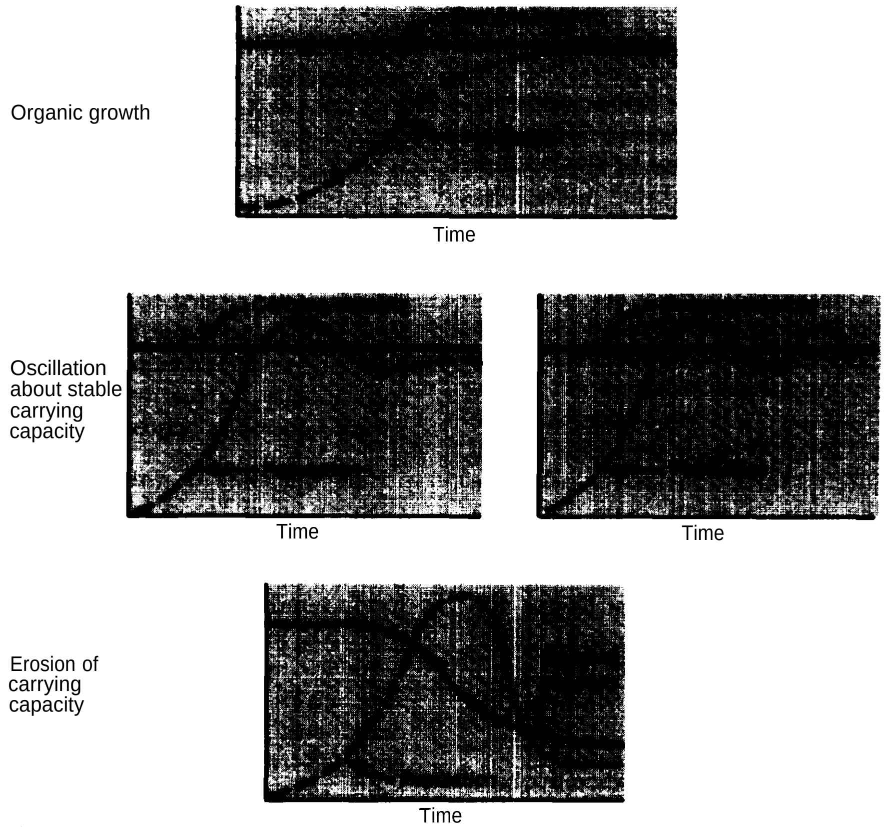
The standard or "reference run" of World 3, based on a continuation of the trends that have characterized the world system since 1900, results in the model output that has given The Limits of Growth its reputation for "gloom and doom" (see fig. 3). In this case the collapse of the system is caused by rapidly expanding population and in-

[1] Jenniter Robinson in Meadows, Richardson, and Bruckmann, op cit , p 408

[18] Dennis L. Meadows, et al, *Dynamics of Growth in a Finite World* (Cambridge, Mass Wright -Allen, 1974), p 8

[19] Meadows, Richardson, and Bruckmann, op cit., p 61

Figure 2.— Possible Global Behavior Modes



SOURCE: *Limits to Growth.*

dustrial output and a diminishing resource base. Essentially the same results are achieved in additional runs with increasingly optimistic assumptions about the five system variables:

- doubling the nonrenewable resource base;
- "unlimited" nuclear power and extensive recycling;
- strict and effective pollution control;
- doubling the average agricultural yield; and
- "perfectly effective" but voluntary birth control.

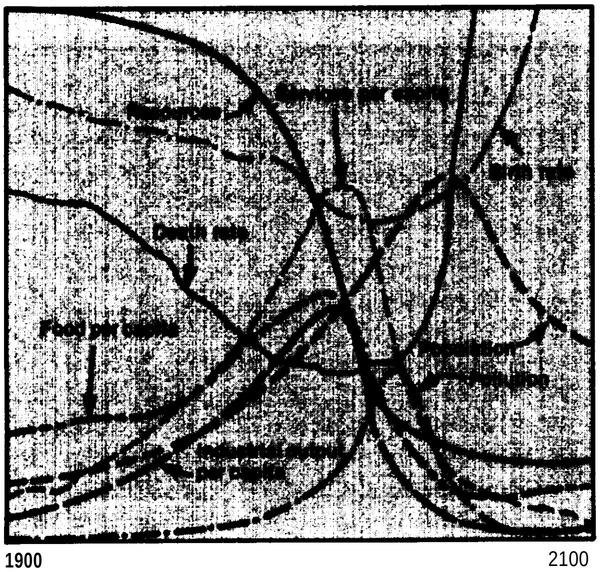
In some of the runs population and industrial production climb to higher levels before collapsing, but–according to this analysis–no single technological change can avert the final catastrophe, nor can any combination of them delay the collapse beyond the year 2100. In some runs the collapse is caused by a resource crisis, in others by a pollution crisis or a food crisis; but no matter what the assumptions, say the authors, "The basic behavior mode of the world system is exponential growth of population and capital, followed by collapse."[20]

In keeping with their second objective, the MIT team also used the World 3 model to identify conditions and policies that would avoid these problems and lead to a stable behavior mode like one of those in figure 2. Continuous growth was ruled out by the basic assumptions of the model; they were looking for an output that represented a "sustainable" world system that would avoid collapse and would also be "capable of satisfying the basic material requirements of all of its people. "[21]

By working backward from the desired outcome to the conditions that would produce it, the authors were able to find a combination of "realistic" policy changes that, implemented simultaneously

[20]Meadows, et al., *The Limits to Growth*, p. 142.
[21]Ibid., p. 158.

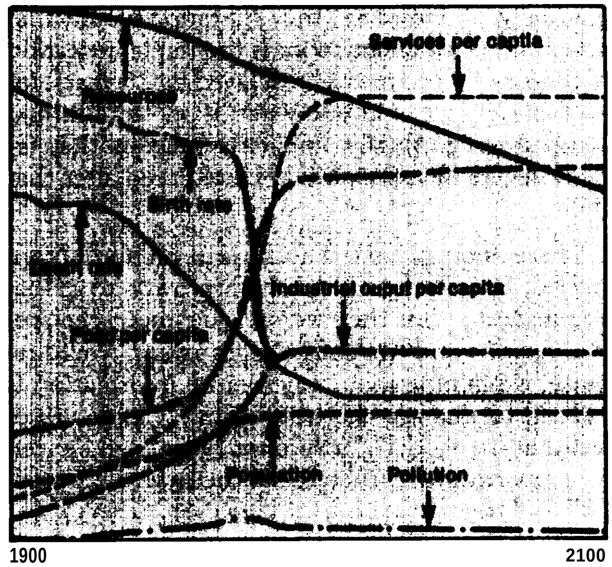
Figure 3.—World 3 Standard Run



The "standard" **world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system. All variables plotted here follow historical values from 1900 to 1970. Food, industrial output, and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialization. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.**

SOURCE: Limits to Growth.

Figure 4.—World 3 Equilibrium Run



Technological policies and growth-regulating policies produce an equilibrium state sustainable far into the future. Technological policies include resource recycling, pollution control devices, increased lifetime of all forms of capital, and methods to restore eroded and infertile soil. Value changes include increased emphasis on food and services rather than on industrial production. Births are set equal to deaths and industrial capital investment equal to capital depreciation. Equilibrium value of industrial output per capita is three times the 1970 world average.

SOURCE: *Limits to Growth,*

in 1975, would lead to an "equilibrium state" (see fig. 4):[22]

- restrict population growth by reducing average desired family size to two children and making "perfect" birth control universally accessible (population stabilizes at about 6 billion in 2050, after a delay inherent in the age structure of the current population);
- restrict capital growth by maintaining average industrial output per capita at the 1975 level and holding the capital investment rate equal to the depreciation rate (excess capacity is used to produce consumer goods and services);
- reduce resource consumption and pollution generation per unit 'of industrial and agricultural output to one-fourth of their 1970 levels (largely through recycling and advanced abatement technologies);
- divert capital to agricultural production in order to produce sufficient food for all people, even if such an investment would be considered "uneconomic;"
- prevent soil depletion and erosion by using some of the agricultural capital for enrichment and preservation (e.g., comporting urban organic wastes and returning them to the land); and
- extend the average lifetime of industrial capital stock through improved durability and maintenance, in order to reduce obsolescence and make more capital and resources available for other sectors.

The authors recognized that different combinations of the above policies might be adopted by different societies, and that "[a] society choosing sta-

[22] Ibid., pp. 160-166.

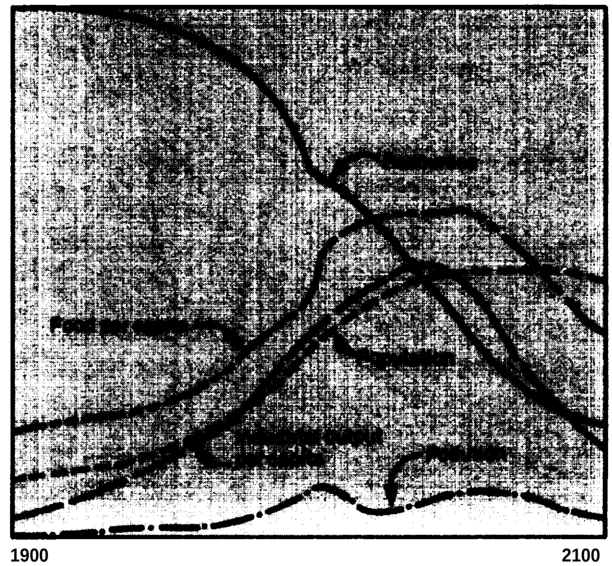
bility as a goal certainly must approach that goal gradually."[23] However, they hastened to add that action must be taken soon: if the implementation of these policies were to be delayed by 25 years, for example, they would not result in an "equilibrium state" (see fig. 5); this implicitly suggests that far more severe measures would be required after that time.

These findings led the authors to call for a "controlled, orderly transition from growth to global equilibrium, " but they were vague about the specific actions and tradeoffs this transition would require, explaining that "much more information is needed to manage the transition. "[24] Some critics feel that the model's "no growth" bias "can be seen as supporting the interests of the materially well-off" and the rich nations.[25] However, others Point out that the equilibrium state necessarily implies a "world-wide radical egalitarian levelling of incomes and property, "[26] yet the MIT team has "almost nothing to say about what should or might happen to poor nations . . . under the policy of no growth. "[27] Because of "their deliberate self-restriction to physical properties of the world," according to another critic, "they have chosen to be unconcerned with politics [and] social structure; "[28] The Limits to Growth speaks instead of the greater demands that will be placed on "humanity's moral resources. "[29] Above all, however, the model's simplification and global aggregation of imperfectly understood factors make it unsuited for generating specific, detailed policy recommendations. This is a limitation shared by other global models:

> The breadth of focus and coherent conceptual development of the world models ensure their utility for clarifying the nature of long-term global problems. However, their limitations render them unsuitable as primary tools of analysis or as tools for detailed analysis of global problems and their solutions. 30

[23]Ibid., p. 167.
[24]Ibid., p. 180.
[25]Keith L. R. Pavitt, "Malthus and Other Economists: Some Doomsdays Revisited," in *Models of Doom*: A *Critique of the Limits* to *Growth*, H. S. D. Cole (eel.) (New York: Universe Books, 1973), pp. 154-157.
[26]Harvey Simmons, "Systems Dynamics and Technocracy)" in *Models of* Doom, pp. 206-207.
[27]Cole in *World Futures* The *Great Debate*, p. 29.
[28]Marie Jahoda, "Postscript on Social Change," in *Models of* Doom, p. 212.
[29]Meadows, et al., The *Limits* to *Growth*, p. 179.
[30]Jennifer Robinson, "worlds 2 and 3," in The *Global 2000 Report to the President* (Washington, D. C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 2, p. 608.

Figure 5.—World 3 Run With Stabilizing Policies Introduced in the Year 2000



If all the policies instituted in 1975 in the previous figure are delayed until the year 2000, the equilibrium state is no longer sustainable. Population and industrial capital reach levels high enough to create food and resource shortages before the year 2100.

SOURCE: Limits to Growth,

Conclusions of World 3

Within these limits, World 3 arrives at three central conclusions that have been influential in the subsequent "futures debate:"[31]

1. If present growth trends in global population, industrialization, resource depletion, pollution, and food production are allowed to continue unchanged, the limits to growth on this planet will be reached sometime within the next 100 years, resulting in a catastrophic decline in both population and industrial capacity.
2. These growth trends can be altered in such a way as to establish economic stability at levels that are both sustainable into the foreseeable future and capable of satisfying the basic material needs of all the world's people.
3. If the people and nations of the world decide to strive for this equilibrium state, the sooner they start working to attain it, the greater their chances for success will be.

[31]Meadows, Richardson, and Bruckmann, op. cit., pp. 67-68.

Similarly, the technical limitations that restrict the utility of World 3 have proven to be a stimulus for subsequent global models, whose purposes increasingly have been to achieve both greater specificity and greater relevance to the needs of policy makers.

World Integrated Model—Mankind at the Turning Point

Origin and Purpose

The World 3 model achieved most of the objectives set for it by the MIT team and by the Club of Rome, but system dynamics was still viewed with skepticism in traditional scientific and policy circles. As a result, the popularized report on the model, The Limits to Growth, was the subject of considerable debate and controversy because of its methods—primarily its radical aggregation of global factors—and because of its vagueness on policy issues. When the club began planning a followup in 1972, therefore, it sought a modeling approach that would accomplish three goals:[32]

- to represent the world as a system of interdependent regions, rather than a single homogeneous unit, and to represent those regions in greater sectoral detail;
- to develop recommendations that would be of more direct relevance to policy makers; and
- to gain greater acceptance from the scientific community by incorporating more "hard data" and, wherever possible, by explicitly employing state-of-the-art theories and methodologies from the relevant academic disciplines.

The model the club chose to support, again with funds from the Volkswagen Foundation, was the World Integrated Model (WIM). This model was developed in parallel by two teams, one led by Mihajlo Mesarovic at Case Western Reserve University in Cleveland and the other by Eduard Pestel (a member of the executive committee of the Club of Rome) at the Technical University in Hannover, West Germany.

The authors first presented their model at a conference for high-level policy makers sponsored by the Woodrow Wilson International Center for Scholars in Washington, D. C., then at the first global modeling conference of the International Institute for Applied Systems Analysis (IIASA) in Austria, and finally at a series of scientific meetings and congresses throughout the world. Only after these formal presentations—and the distribution of technical documentation to selected experts—did they release the popular description of the model in the fall of 1974.

[32]Ibid., pp. 72-74.

Structure and Assumptions

The WIM methodology is based on Mesarovic's "multilevel hierarchical systems theory," which views the world in terms of five interrelated planes or strata:

- the environmental stratum, which combines geophysical and ecological factors and corresponds roughly to the natural "carrying capacity," although perhaps too superficially to satisfy some environmentalists;
- the technology stratum, which embraces activities whose biological, chemical, or physical terms involve mass and energy transfer;
- the demographic-economic stratum, which combines the human population and industrial capital of World 3 and, with the environment stratum, makes up most of the model's content;
- the group stratum, made up of sociopolitical institutions, policies, and decisions, which are usually represented as sets of alternative scenarios among which the model user chooses; and
- the individual stratum, reflecting personal attitudes and values, again represented by alternative scenarios to be selected by the model user.

According to the theory, these levels ordinarily operate with a fair degree of independence, although they can become highly interactive under "crisis" conditions. The authors therefore feel that their model can help us to understand and predict the system's behavior in both present and future crises.[33]

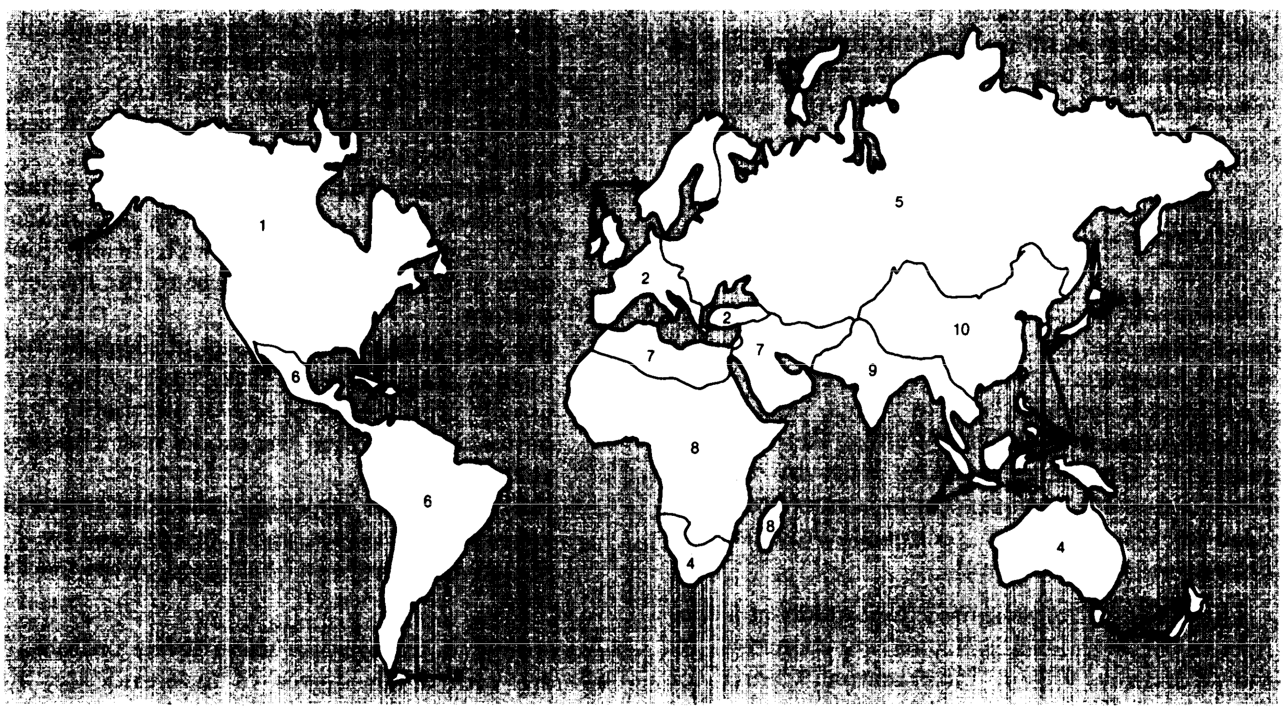
The major improvement in the WIM representation of the world system, however, is its greater geographic and economic detail (regionalization and disaggregation). Instead of a single homogeneous world, the model contains 10 regions made up of similar countries (see fig. 6), although in some runs they are grouped in three or four blocs. As a result, WIM can represent varying levels of development and resource endowment, as well as cultural and environmental differences; and it can therefore be used to investigate potential regional (as opposed to global) problems and crises. In addition, because these regions are connected by a trade network, WIM can be used to investigate the potentially mitigating effects of international trade (see fig. 7). Within each region, physical and economic sectors are differentiated into numerous subcategories—85 age groups for population, 19 categories for industrial capital, five for energy capital, two for agricultural capital, and so on. From the point of view of an economist, in fact, WIM is a collection of regional economic models. The resulting mathematical model is quite large: World 1 contained only 40 equations, and World 3 about 200, while WIM (according to its creators) contains over 100,000.[34]

Another improvement, one that is more directly relevant to policy applications, is the model's interactive design. The model user is allowed to estimate social and political behavior by selecting among alternative scenarios in the individual and group strata, thereby manipulating certain variables in such a way as to test a wide range of policy assumptions about energy prices, food exports, capital investments, and development aid. In addition, WIM's various submodels can be used independently to generate and test alternative policies for specific countries and regions. This capability

[33] Jennifer Robinson, "Mesarovic-Pestel World Model," in The *Global 2000 Report to the President*, vol. 2, p. 616.

[34] Cole i, *World Futures*: The Great Debate, p. 34

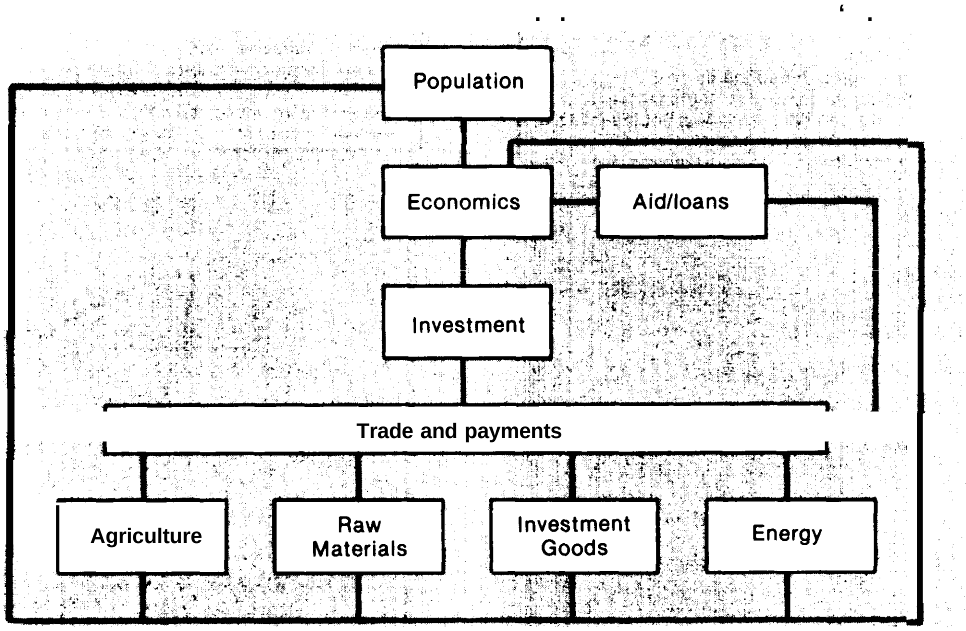
Figure 6.—Regionalization of the World integrated Model



NOTE: Later versions of World Integrated Model divide regions 1, 5, 6, and 7 into two regions each, for a total of 14 regions; they also have the capability of subdividing these new regions into five subregions each, depending on the level of detail required.

SOURCE: Mankind at the Turning Point.

Figure 7.—Block Diagram of the Basic Elements of the World Integrated Model



SOURCE: Command and Control Technical Center.

was in fact one of the stated objectives of the modelers:

> We hoped thus to furnish political and economic decisionmakers in various parts of the world with a comprehensive global planning tool, which could help them to act in anticipation of the crises at our doorstep and of those that loom increasingly large in the distance, instead of reacting in the spirit of short-term pragmatism.[35]

In keeping with this objective, which is shared by the Club of Rome, the WIM team at Case Western Reserve has actively marketed their model, using satellite-telephone patches to make presentations to prime ministers and other officials in at least 18 different nations.

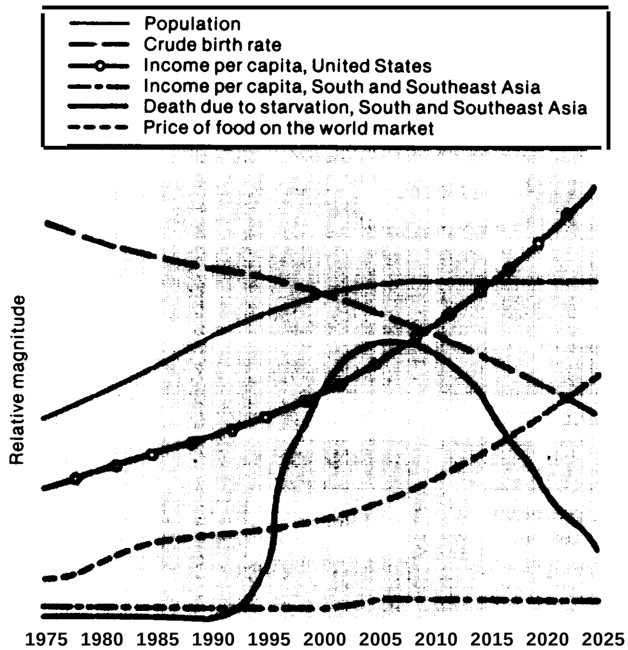
Findings of WIM

The WIM model has shown its versatility in extensive use for policy testing, both to evaluate alternative scenarios within its own assumptions and to test the scenarios and assumptions of other modelers and futurists.[36] Because the purpose and output of the model vary significantly from user to user and run to run, however, it is difficult to isolate any particular "results," although several test runs are illustrative. The reference or "historical scenario" run of the model, based on a continuation of present trends, results in the model output shown in figure 8: a steady increase in the real cost of food on the world market, which would also drive up domestic prices in the United States, and a catastrophic increase in the number of deaths caused by starvation in South Asia. The alternative "isolationist scenario" (fig. 9) indicates that, should the United States act to keep domestic food prices down by restricting exports, starvation in South Asia comes sooner and is even more widespread. In another pair of policy tests (fig. 10), the model output suggests that a policy of low, fixed oil prices leads to a catastrophic economic decline in the developed world when the resource is exhausted, whereas "optimal" price increases (per-

[35] Mihajlo D. Mesarovic and Eduard Pestel, *Mankind at the Turning Point* (New York: Dutton, 1974), p. Ix.

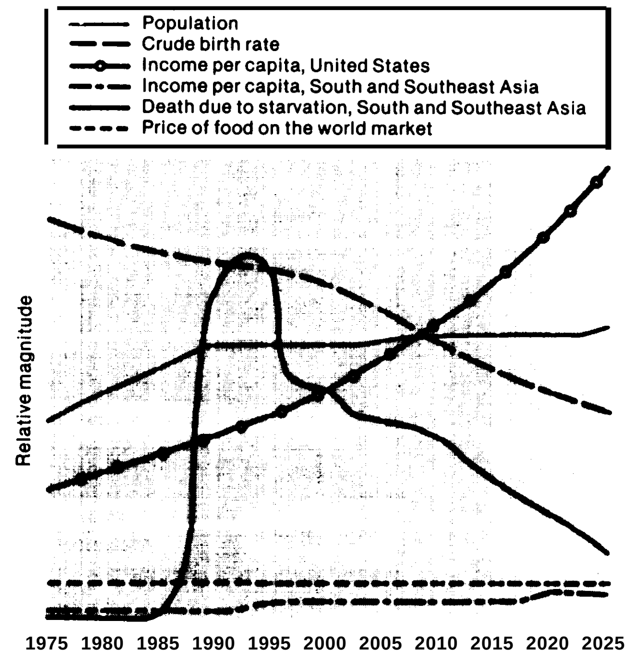
[36] See for example Barry B. Hughes and Mihajlo D. Mesarovic, "Testing the Hudson Institute Scenarios" (Washington, D. C.: U.S. Association for the Club of Rome, Sept. 1979), mimeograph.

Figure 8.—WIM Historical Scenario



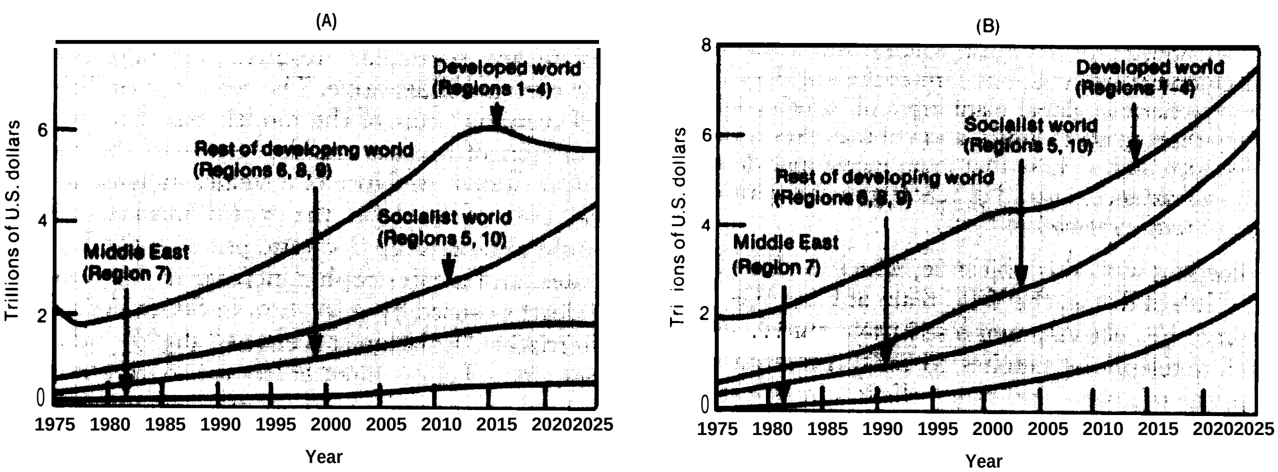
SOURCE: Systems Research Center, Case Western Reserve University.

Figure 9.—WIM Isolationist Scenario



SOURCE: Systems Research Center, Case Western Reserve University,

Figure 10.–Comparison of WIM Low" and Optimal"Price Oil Scenarios



Cheap energy in the form of oil has been a prime fuel for the unprecedented growth of the world economy in the 1950's and 1960's. The dramatic increase in oil prices in 1973 was viewed as a catastrophe. However, computer analysis of our world system model indicates that the continuation of what amounts to overexploitation of oil, spurred by an unreasonably low price, would lead to major dislocations because of the exhaustion of reserves and the lack of motivation to develop substitutes in time. Pursuance of short term objectives would lead to major dislocations in **the** long run (see A). A much **more beneficial development for all concerned results from the "optimal price scenario" in which the price is gradually increased up to the "optimum" level. Such a policy would bring in the substitutes in a more regular fashion while prolonging the reserves. Both exporting and importing regions would fare better (see B). It is only by taking a global and long term view that such a course of development, most beneficial to all concerned, can be identified.**

SOURCE: *Mankind at the Turning Point.*

mitting gradual adaptation and substitution) benefits both oil producers and consumers; a third oil-price scenario (not shown) suggests that increases above the "optimal" level leave all regions worse off.[37]

Conclusions of WIM

From these and numerous additional interactions with the model, the authors arrive at several conclusions about the nature of the world system and the management of future development:[38]

- the current crises in agriculture, energy, etc., are not transient but persistent, and represent the first signs of an "oncoming era of scarcity ;"
- the solutions to these crises cannot be found through isolated, short-term, or narrowly nationalistic strategies, but only through an integrated global context and "in the spirit of truly global" cooperation . . . guided by a rational master plan for long-term organic growth;" and
- "the time that can be wasted before developing such a global world system is running out ."

The model indicates that oil, substitutes for oil, and agricultural land will be the greatest constraints on growth. To address these problems, the authors recommend a policy of "organic growth," based on a recognition that the world system is a "collect ion of functionally interdependent parts, "[39] This policy, which would encourage growth where needed and discourage it where it "threatens not only that part but the whole as well, " include such specific steps as the following:[40]

- encourage worldwide diversification of industry to achieve a truly global economic system;
- build up the economic base and especially the export potential of the poorest countries so they can pay for food imports;
- give food aid to the poorest countries, but give investment aid only in the form of "intermediate" or appropriate technology; and
- carry out effective social and institutional reforms, because the required economic transfers are impossible under prevailing international economic arrangements.

The authors suggest that unless such steps are taken, spreading regional collapse and international tension will, like falling dominoes, eventually reach the developed world. If these and other steps are taken, on the other hand, "the world growth rates implied by (WIM's) computer results are much closer to those of Kahn and Wiener than to those of Meadows and Forrester. "[41]

U.S. Government Use of WIM

More recently, former members of the modeling team have designed a specially tailored version of WIM for the U.S. Department of Defense.[42] The model, which is fully operational, is maintained and operated by the Command and Control Technical Center (CCTC) in support of the Plans and Policy Directorate (J-5) of the Joint Chiefs of Staff. J-5 is currently creating a new division, specifically devoted to long-range analysis, which will use the model to develop projections of global systems behavior for use in long-range national security planning. At present, the model is being developed to provide data on political, economic, and demographic conditions under various subcontingencies of four basic scenarios or "future worlds" defined by J-5:

- "A-muted bipolarity," essentially a reference run based on current trends and international relations;
- "B-superpower dominance (conflict mode)," including contingencies representing different levels of East-West conflict;
- "C-superpower dominance (cooperation mode);" and
- "D-devolution of power," representing a future in which the superpowers must share world power with other groups of nations, and including contingencies for potential North-South conflicts, such as an oil embargo.

[37]Meadows, Richardson, and Bruckmann, op. cit., p. 83
[38]Mesarovic and Pestel, op. cit, pp. 85, 157.
[39]Ibid., pp. 5, 66.
[40]Cole in *World Futures: The Great Debate*, pp. 35-36.

[41]Ibid., p. 36.
[42]Material in this and the following paragraph is based on interviews with Col. Wilbert Jenkins, J-5, and Maj. Gary Knutson, CCTC; see also *World Integrated Model Multilevel Hierarchical Theoretic Concepts*, CCTC Technical Memorandum TM 197-79 (Washington, D.C.: U.S. Defense Communications Agency, June 15, 1979).

These WIM projections will become an input to the Joint Long-Range Strategic Appraisal beginning with its 1982 revision. CCTC also plans a complete update of its data base (facilitated by a new software package) and further refinements in WIM itself that may make it a more flexible tool for determining future military requirements. For instance, CCTC's version of WIM contains 12 geographical regions rather than 10 and will soon be expanded to 14, with the further capability of subdividing each new region into five subregions; it also contains 87 rather than 85 age groups and (for the United States and Soviet Union) a labor-skills submodel that further divides the population into male or female and urban or rural; and there have been similar refinements in the agricultural and materials submodels. These improvements create data problems, however, since reliable data are not available for many subregions and sectors. CCTC is working with the Bureau of Mines to update and expand the data base for the materials sector; in addition, J-5 has instructed CCTC to contact other Federal agencies about possible coordination of global modeling and strategic assessment activities. Such coordination might be facilitated in at least two cases by the fact that the Department of Agriculture, as well as the Bureau of Mines, is already using a version of WIM.

Latin American World Model—Catastrophe or New Society?

Origin and Purpose

When the Club of Rome presented the preliminary results of World 3 at a 1970 meeting in Rio de Janeiro, the reaction of the mostly Latin American audience was strongly negative. They felt that predictions of global crises, based on extrapolation of present trends and arrangements, reflected a parochial developed-world perspective; for two-thirds of the world's people such crises are already at hand. The audience refused to accept scenarios that implicitly curbed development and widened the income gap, and they felt that policies aimed at achieving a state of global equilibrium would merely ensure that the present disparities and inequities in the world system are perpetuated. They resolved, therefore, to design a model of an egalitarian "ideal society" in which basic human needs (not profits) would be the basis for resource allocation. The purpose of the model is to demonstrate the material viability of such a society, and thereby to demonstrate "that the different countries and regions of the world (particularly the poorest) could reach the goals we advocate in a reasonable period of time," relying primarily on their own human and economic resources.[43]

This global modeling effort was carried out at the Fundacion Bariloche in Argentina, with principal support from the International Development Research Center in Ottawa, and was first presented at the second IIASA modeling conference in Berlin in October 1974. An expanded version of the model, developed for the International Labor Organization (ILO), was warmly received at the 1976 World Employment Conference in Geneva, where "basic needs" were formally adopted as a major target of development.[44] The model continues to have considerable impact through United Nations organizations, including the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the United Nations Industrial Development Organization (UNIDO) as well as ILO, and it is by far the most popular global model among scientists and decisionmakers in the Third World.[45]

Unlike World 3 and WIM, which provide conditional descriptive forecasts of global trends, the Latin American World Model (LAWM) is openly and insistently normative—it is not concerned with "predicting what will occur if the contemporary tendencies of mankind continue, but rather with sketching a way of arriving at the final

[43] Amilcar O. Herrera, et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Center, 1976), p. 8.

[44] Cole in *World Futures: The Great Debate*, p. 39.

[45] Meadows, Richardson, and Bruckmann, op. at., p. 92.

goals of a world liberated from underdevelopment and misery. "[46] Its purpose is not to demonstrate that certain changes might bring the present world system into equilibrium, but rather "to show the feasibility of solving the fundamental problems through deep socio-political changes."[47] The model is also distinguished by its emphasis on the ideological issues involved in global modeling: the modeling team was composed of humanistic socialists,[48] and on questions of development and redistribution they "explicitly take up a stance favourable to the Third World in general, and to Latin America in particular."[49]

Structure and Assumptions

The LAWM team's goals and purposes lead them to include some rather unusual assumptions in the structure of their model. For instance, the model divides the world into four regions (later 15), each of which is treated as an economic unit, which "presupposes total collaboration between the countries forming it."[50] The model contains "simplistic" trade linkages: the contribution of international trade relative to regional gross national product (GNP) is held constant at the 1970 level, and all trade deficits are eliminated by 2000.[51] Instead, each region satisfied basic needs through "autarchy, " using almost exclusively local economic resources. However, these resources are assumed to be available in unlimited quantities and at constant cost: after a static analysis of current resource data, the modelers conclude that "the environment and its natural resources will not impose barriers of absolute physical limits on the attainment of [an ideal] society," at least not within a "historically significant time-scale. "[52] As a result, they do not include these physical factors in the computer model, and in this specific their model reflects a technological optimism akin to Herman Kahn's.

However, the authors do assume a radical change in the sociopolitical factors that control patterns of resource use—i.e., an equal distribution of consumption between regions and a total, egalitarian redistribution of income within regions. In addition, the model includes no assumptions about population policies, although it does include several untested assumptions about the effect of living conditions on demographic change. LAWM also appears to assume automatic growth in productivity through technological progress, at no cost, at rates between 0.5 and 1.5 percent annually depending on the sector.[53]

LAWM is essentially an economic model that operates through optimization procedures; i.e., it has five production sectors representing basic needs—food, housing, education, capital goods, and other goods and services—to which labor and capital are allocated through optimal control techniques in such a way as to maximize life expectancy at birth, which is taken to be the best indicator of general living conditions. These calculations proceed independently for each region from 1960 to 2060, but all countries are assumed to follow optimal policies after 1980.

Findings of LAWM

The standard or reference run of this optimization model indicates that all regions except Asia can reach their basic needs targets within 30 years. Developed nations (including the Communist world) "can reach high levels of well-being even if their economic growth rate is reduced drastically in the future" (fig. 11); in reality, economic growth is restricted to between 1 and 2 percent—far below the developed region's capacity for growth—which the authors acknowledge "assumes a political decision. "[54]

Latin America could fulfill basic needs by the early 1990's by maintaining a relatively high investment rate, particularly in housing and education (fig. 12). The output for Africa closely resembles that for Latin America, although basic needs are not met until 2008 and some shortfalls occur in the housing sector.

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[46] Amilcar O. Herrera, *Proceedings of the 2d IIASA Global Modeling Conference* (Berlin, 1974), quoted by Meadows, Richardson, and Bruckmann, op. cit., p. 91.

[47] Hugo D. Scolnik, et al., "The Bariloche Model," in Meadow, Richardson, and Bruckmann, op. cit., p. 247.

[48] Jennifer Robinson, "The Latin American World Model," in *The Global 2000 Report to the President*, vol. 2, p. 647.

[49] Cole in *World Futures The Great Debate*, p. 48.

[50] Herrera, et al., op. Lit., p. 44.

[51] Robinson, "The Latin American World Model," p. 642

[52] Herrera, et al., op. cit., p. 8.

[53] Robinson, "The Latin American World Model," pp. 639, 643

[54] Herrera, et al., op. cit., pp. 87, 100-101.

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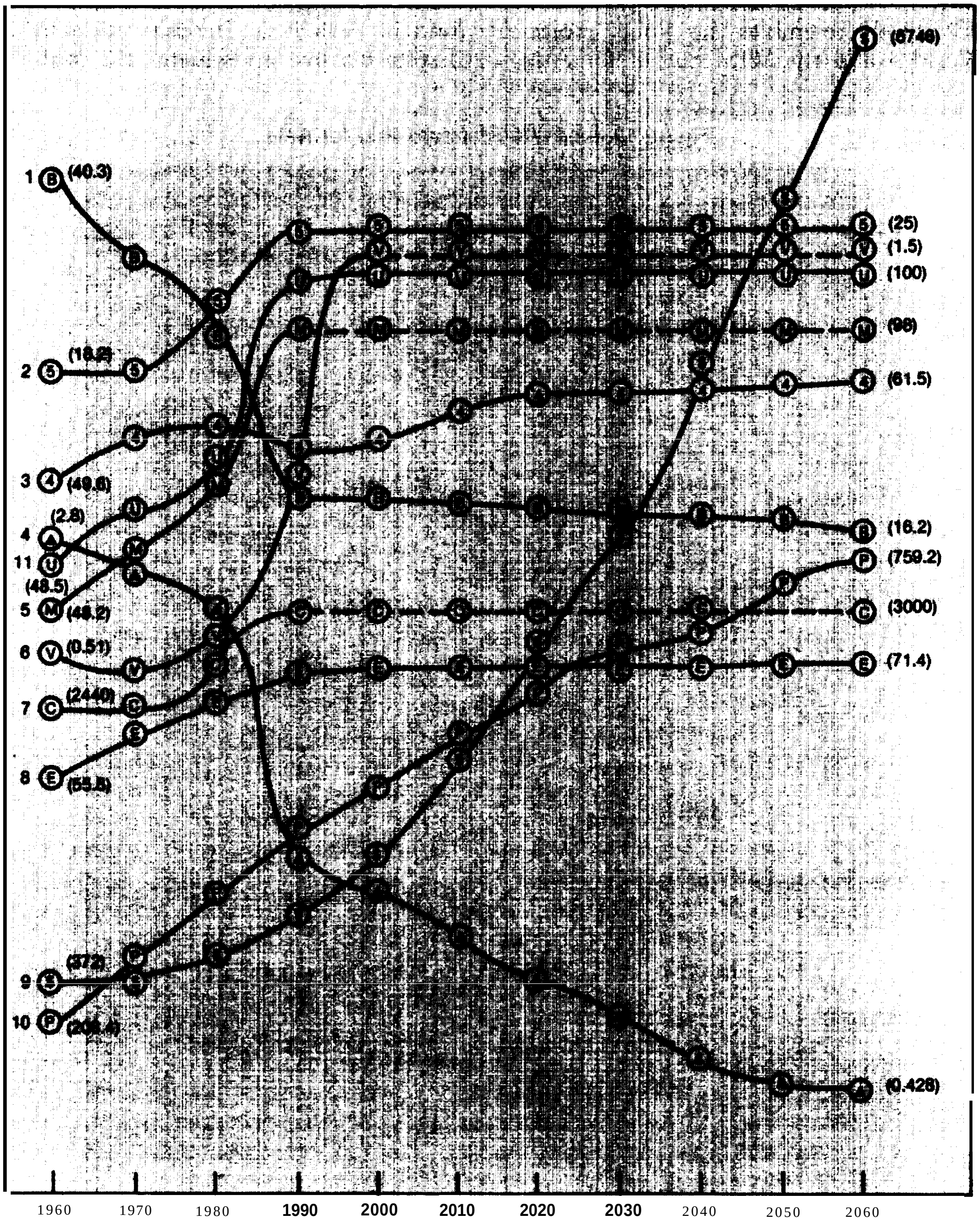
Figure 12.— LAWM Standard Run for Latin America



Key;

1 (B) Birthrate
2 (5) Percentage of GNP allocated to sector 5
3 (4) Percentage of GNP allocated to sector 4
4 (A) Population growth rate
5 (M) Enrollment
6 (V) Houses per family
7 (C) Total calories
8 (E) Life expectancy
9 ($) GNP per capita in 1960 dollars
10 (P) Total population
11 (U) Urbanization

SOURCE Catastrophe or New Society?

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not keep up with population growth; daily food intake peaks at less than 3,000 calories per capita in 2008 and declines steadily thereafter. (These investments would also divert resources from the satisfaction of other basic needs, and they would probably prevent economic growth if investment in capital goods were not fixed at 25 percent.) Only an effective population policy and the use of nonconventional foodstuffs, both of which the authors advocate, could avoid catastrophe in Asia under these conditions.

The policy tests conducted with LAWM indicate that capital transfers from the industrialized countries (in isolation from other measures) would have little effect on the above outcomes, but they also reveal that both technological progress and internal income redistribution are vital to achieving regional goals.

- In the "international solidarity" run, the developed nations transfer capital aid to Africa and Asia at a rate that rises from 0.2 percent of GNP in 1980 to 2.0 percent in 1990 and thereafter. The result is higher investment rates and faster economic growth in the industrialized nations (in order to compensate for the aid), but very little effect on the time needed to satisfy basic needs elsewhere and a negligible impact on the food shortage in Asia.
- In the "technological stagnation" run, on the other hand, growth in economic production due to technical progress falls to zero between 1980 and 2000 and remains there. The outcome is disastrous in every region except the developed nations. Latin America requires a longer period of time to satisfy basic needs, particularly food and housing, and in Africa and Asia "the economic system finally collapses" sometime between 1990 and 2020 as population steadily outstrips production.
- By far the greatest difference in results, however, comes from the "historical" run, in which the assumption of egalitarian intraregional redistribution is replaced by a pattern of consumption that reflects current income distributions and socioeconomic structures. To satisfy basic needs in the same period of time under these conditions would require economic growth rates of 10 to 12 percent in the developing countries, rates which "are in fact impossible to attain. " The authors conclude that "at the very best" their goals would be delayed by two or three generations, and would require 3 to 5 times more resources, under these conditions.[55]

Conclusions of LAWM

The conclusions the LAWM team draws from its interactions with the model do not always reflect the above results (apparent discrepancies are noted in parentheses):[56]

- "it is possible to control population growth to the point of equilibrium by raising the general standard of living" (population stabilizes only in the developed regions, and is still growing globally at a rate of 1.1 percent per year in 2040);
- "if the policies proposed here are applied, all of humanity could attain an adequate standard of living within a period little longer than one generation" (this is true for Asia only with an effective population policy and considerable development aid);
- "this equilibrium could be achieved on a global scale well before the earth's capacity to produce food—the only foreseeable physical limitation within the time horizon of the model—is fully exploited even if food production continues to be based on currently available technology" (the model assumes considerable technical progress at no cost in agriculture and all other sectors, and fails to achieve its goals if technology stagnates);
- "[the] obstacles that stand in the way of the harmonious development of humanity are not physical or economic in the strict sense, but are essentially sociopolitical;" and
- "[the] goals are therefore [to be] achieved . . . by a reduction of nonessential consumption; increased investment; . . . the rational use of land . . . the egalitarian distribution of basic goods and services; and . . . the implementation of an active policy to eliminate deficits in international trade."

[55] Ibid., pp. 106-107.
[56] Ibid., p. 107.

United Nations Input-Output World Model— The Future of the World Economy

Origin and Purpose

Like LAWM, the United Nations Input-Output World Model (UNIOWM) represents a Third World reaction to the unpalatable conclusions of The Limits to Growth. However, its central concern is not the satisfaction of basic needs, but rather the narrowing of the income gap between the rich and poor nations. The model was commissioned in late 1972 by the Centre for Development Planning, Projections, and Policies (CDPPP), a U.N. agency responsible for long-range integrated planning. Initial financial support came from the Government of the Netherlands, and subsequent funding was obtained from the U. N., the Ford Foundation, and the National Science Foundation. Wassily Leontief, the project director, outlined the concepts behind the model in his acceptance speech for the Nobel Prize in economics in 1973; the work of collecting data and building the model was carried out by Anne Carter, Peter Petri, and others at Brandeis University. Petri presented the model at the Fifth IIASA modeling conference in September 1977, shortly after The Future of the World Economy was released in New York.

The study was conducted under U.N. auspices and direction. Although its findings did not represent official U.N. recommendations, the model's primary purpose was to determine whether physical or environmental limits would pose a significant barrier to the economic growth targets set by the U.N.'S International Development Strategy, which had been proposed by the General Assembly in 1970 as the basis for the Second Development Decade. As modified and expanded by various U.N. agencies, these targets include the following:

- reducing the average income ratio between the developing and developed countries by almost 50 percent, from 12:1 to 7:1;
- improving internal income distribution to eradicate mass poverty;
- creating 1 billion new jobs in the developing world by 2000;
- satisfying the basic needs of all people;
- increasing food production in developing countries by at least 4 percent per year; increasing the developing nations' share of the world market in manufacturing to 14.3 percent by 1985 and 25 percent by 2000; and
- achieving a new international economic order (NIEO), including stabilized commodity prices, increased financial and technology transfers, open markets for the less developed countries' (LDC) exports, and a code of conduct of translational enterprises.

Structure and Assumptions

The authors describe UNIOWM as "basically a general-purpose economic model and thus applicable to the analysis of the evolution of the world economy from other points of view, "[57] notably the environmental. However, Leontief has cautioned that:

> We cannot predict the future of the world economy. However, we can rule out of our expectations future scenarios that are internally inconsistent and thus impossible.
>
> To rule out internally inconsistent expectations we need to construct a model that guarantees internal consistency . . . by visualizing the world as a system of interdependent process in which each process . . . generates certain output and absorbs a specific combination of input.[58]

The rigorous accounting required by this input-output analysis forces the model to balance the growth of one economic sector against its effect on other sectors; similarly, imports and exports in one region must be balanced against the imports and exports of other regions. This technique also permits "an unusual degree of detail" in representing particular industries or regions, which is "advantageous" because of its "relatively specific policy significance."[59] On the other hand, critics have

[57] Wassily Leontief, Anne Carter, and Peter Petri, *The Future of the World Economy: A United Nations Study* (New York: Oxford, 1977), p. 7.

[58] Wassily Leontief, "Structure of the World Economy: Outline of a Simple Input-Output Formulation" (Nobel Memorial Lecture), *American Economic Review*, December 1977, p. 823.

[59] Leontief, Carter, and Petri, op. cit., p. 8.

questioned whether this level of explicit detail is worthwhile or justifiable, particularly since it demands an enormous amount of data, much of which had to be adapted from other information and data bases.[60] UNIOWM's population sector, for example, merely assumes the projections prepared by the U.N. Population Division in 1973 (see app. A).

The model divides the world into 15 regions composed of fairly homogeneous economies, although for purposes of interpretation and presentation of results these regions are further aggregated in three categories: developed nations (eight regions), resource-rich LDCs (three regions), and resource-poor nations (four regions). Each region's economy contains 45 sectors of economic activity, described by 175 equations with 229 variables. Prices are calculated in a separate submodel, and (as in LAWM) the representation of international trade has been kept "almost artificially simple."[61] The environmental sector includes eight pollutants and five types of abatement activities, but the model does not reflect the effect of development on ecological systems, nor does it contain any other feedback loops; "it cannot, in any sense, be viewed as a dynamic model."[62] The model's equations are solved simultaneously, usually at 5-year intervals, in order to provide "snapshots" of the world in 1980, 1990, and 2000.

The model can be applied to a wide variety of tasks, but its utility is limited by its large data requirements and by the many controversial assumptions that have been included. This has led one critic to conclude that:

> The huge number of assumptions made in estimating time trends for input-output matrices makes for confusion when it comes to considering the model as a whole. There are so many assumptions that one is hard put to evaluate the reasonableness of the total picture.[63]

Nevertheless, the model could be and has been used for a wide range of policy tests that reflect the interests of the modelers and the organizations that commissioned them.

Findings of UNIOWM

The study's optimistic findings, particularly that "no insurmountable physical barriers exist within this century to the accelerated development of the developing regions" and that "pollution . . . is a technologically manageable problem,"[64] received widespread attention in the media, where it was sometimes reported that UNIOWM "discredited" The Limits to Growth. However, the authors have cautioned that the model "cannot settle, and was not designed to settle, the many fundamental questions raised in The Limits-to-Growth debate."[65] And in fact the optimism of these general statements is not supported by the specific results of most of UNIOWM scenarios.

Policy tests conducted for the UN have included a number of different scenarios relating to economic growth rates and per capita income gaps.

- The "old economic order" scenario is based on historical trends in internal and external investment and existing international economic arrangements. Income per capita grows in all three categories of nations but income gaps increase, despite decelerating growth in the developed regions after 1990, and some LDCs would face an absolute decline in living standards (see fig. 14). This scenario "turns out to be rather pessimistic," according to the authors, and because of its dim economic prospects for the developing regions it is "downplayed in the UN documentation."[66]
- The standard run, based on the minimum growth targets of the International Development Strategy (IDS), also turns out to be relatively pessimistic. Because of their higher rates of population growth, accelerated economic growth in the LDCs does not lead to corresponding gains in GNP per capita. The income gap between developed and less developed regions remains at the current 12:1 ratio.

Sos_am Cole, G/oba[LIo&/s and [he *International Economic Order A Paper for the UNITAR Project on the Future* (New York: Pergamon Press, 1977), p. 22; and Jennifer Robinson, "(J, N. World Model," in *The Global 2000 Report to the President*, ,01.2, p. 649

[61] Robinson, "U.N. World Model," p. 652.

[62] Meadows, Richardson, and Bruckmann, op. cit., p. 167; a similar criticism could be made of WIM.

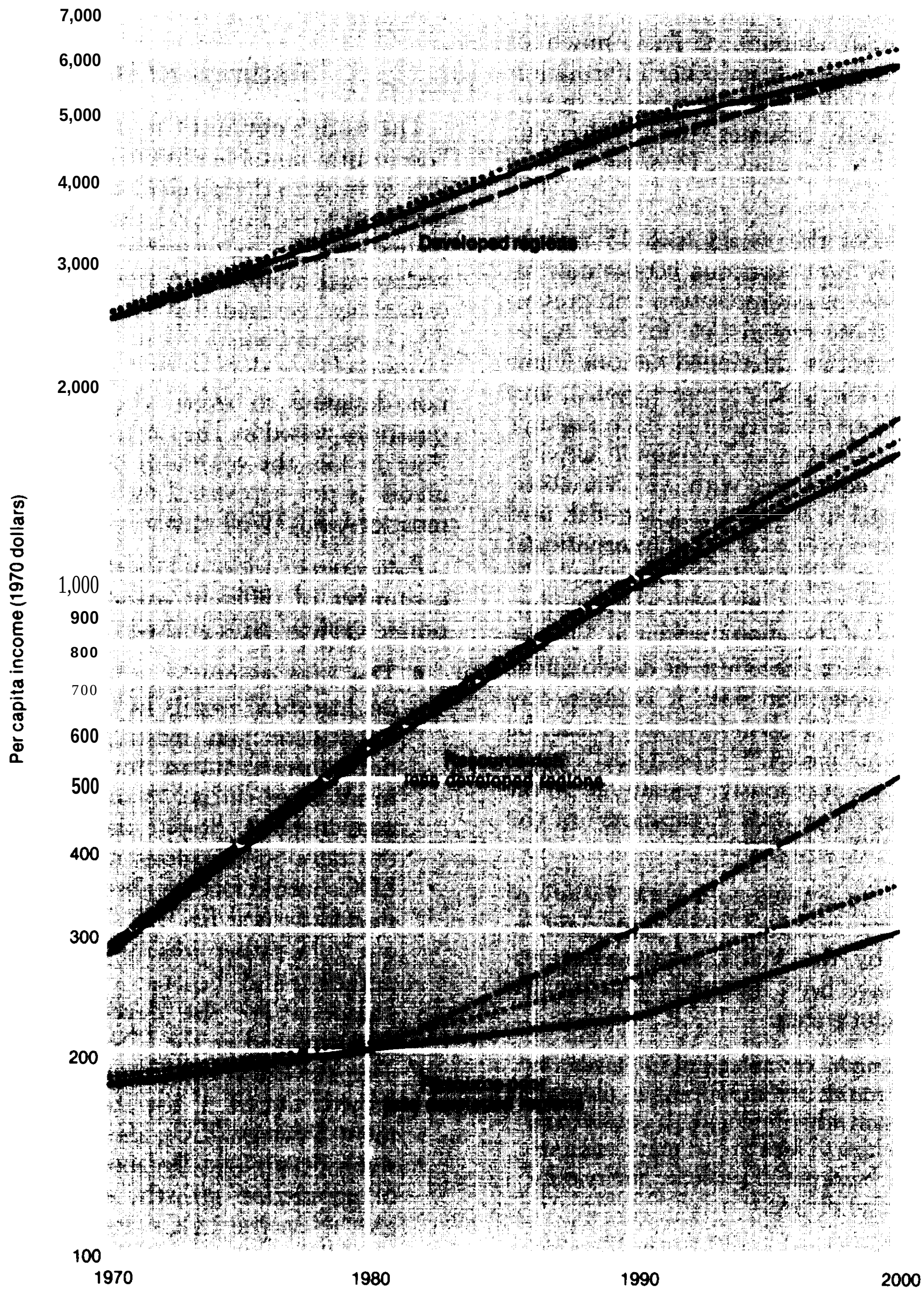
[63] Robinson, "U.N. World Model," p. 652.

6+ Leontief, Carter, and Petri, op. Cit., pp. 48-49.

[65] Peter Petri, "An Introduction to the Structure and Applications of the United Nations World Model," *Applied Mathematical Modeling*, vol. 1, No. 5, June 1977, p. 262.

[66] Leontief, Carter, and Petri, op. cit., p. 73; Robinson, "U N. World Model," p. 653.

Figure 14.—Regional Economic Growth Under Three UNIOWM Scenarios



Projected economic development of the developed regions of the world, the resource-poor less developed regions and the resource-rich less developed regions is shown to the year 2000 under the old-economic-order scenario (*solid black lines*), the new-economic-order scenario (*broken black lines*) and the arms-limitation scenario (*dotted lines*). For the resource-poor less developed regions the levels of per capita income and consumption (not shown) grow much faster under the arms-limitation scenario than under the old-economic-order scenario, but not so fast as under new-economic-order scenario, where income targets are prespecified.

SOURCE: Leontief, "The World Economy of the Year 2000," *Scientific American* 243.3, September 1980, p. 231.

- Four additional runs were then conducted by altering the standard or IDS scenario in such a way as to reflect more optimistic assumptions about: 1) resource endowments; 2) increased foreign aid from the developed regions; 3) fewer constraints on balance-of-payment deficits; and 4) faster agricultural investments to achieve food self-sufficiency in low-income Asia.

None of these scenarios, however, was capable of producing the desired reduction in per capita income ratios. In two final scenarios, therefore, the authors preset the model in such a way as to roughly halve the income gap by 2000 and close it completely by about 2050, and then solved its equations to determine the investment and growth rates that would produce the desired results:

- Scenario "C," based on the U.N.'s "low" population growth projections (see app. A), requires a 6.9 percent GNP growth rate in the LDCs to reduce the income ratio to 7.15:1 by 2000.
- Scenario "X, " based on the U.N.'s "medium" population projections, requires an even higher GNP growth rate of 7.2 percent in the LDCs and reduces the income ratio only to 7.69:1. Scenario "X" also requires a fivefold increase in overall agricultural output in the developing regions, including a nearly tenfold increase in resource-poor Latin America.

In subsequent policy tests, UNIOWM has been used to examine the economic consequences of mineral- and energy-conservation strategies. A study of the future production and consumption of nonfuel minerals, based on the resource conservation strategies of the Economic Council of Canada, is nearing completion but has yet to be publicly documented.[67] Another study, conducted for the U.S. Department of Commerce, compares the "old economic order" scenario with an "energy conservation" scenario based on the maximum reasonable reduction in fossil fuel consumption over the next 20 years through the substitution of labor and capital for energy. It revealed that energy conservation could reduce the balance-of-payments deficits of both developed regions and resource-poor LDCs and allow increased GNP growth in the latter, but that the capital requirements for conservation would require a 17- to 23-percent increase in the savings rate.[68]

More recently, Leontief has conducted two studies of the economic implications of the NIEO and of worldwide military spending, with funding from the U.N. and from American disarmament organizations.[69] In the NIEO scenario, the resource-poor LDCs are allowed to import whatever quantities of goods and services are required to reduce income ratios by 50 percent by the year 2000, with their balance-of-payments deficits–up to 75 percent of their imports—to be financed by "extraordinary credits" from the developed regions and resource-rich LDCs, carrying a nominal 5-percent interest rate. The model output for this scenario (see fig. 1.4) shows that the developed regions, which would have to "work overtime . . . to provide [these] huge amounts of economic aid," would have a higher GNP but lower per capita consumption in 2000, at which time they would be allocating 3.1 percent of their total GNP to development assistance. Leontief himself doubts that such a plan could be implemented:

> On the whole this projection of the future development of the world economy under the new economic order suggests that the practical possibility of carrying out such an optimistic program must be seriously questioned.[70]

As an alternative, Leontief proposes an "arms limitation" scenario, noting that the current half-trillion-dollar annual worldwide defense spending represents "the largest existing economic reserve that might be utilized to accelerate the growth of the resource-poor less developed regions. " Where the "old economic order" scenario assumed that all regions would continue to devote the same percentage of their respective GNPs to defense that they had in 1970, the "arms limitation" scenario assumes that by 2000 the defense expenditures of the United States and the Soviet Union would be reduced by one-third, and that all other regions

[67] Meadows, Richardson, and Bruckmann, op. cit., p. 175; Robinson, "U.N. World Model," p. 653.

[68] Anne P. Carter and Alan K. Sin, "An Energy Conservation Scenario for the World Model," prepared for the Bureau of International and Economic Policy, U.S. Department of Commerce, November 1977, p. 2.

[69] Meadows, Richardson, and Bruckmann, op. cit., p. 175.

[70] Wassily W. Leontief, "The World Economy of the Year 2000," *Scientific Amemxm*, vol. 243, No. 3, September 1980, p. 230.

would reduce defense spending 25 percent by 1990 and 40 percent by 2000. The savings realized in each region would first be used to satisfy its own civilian needs, but the developed regions would allocate 15 percent of their savings to development aid by 1990 and 25 percent by 2000. The model output for this scenario (see fig. 14) indicates that per capita income and consumption in the resource-poor LDCs would increase far faster than under the old economic order. Since developed-region defense savings would be given to LDCs in the form of direct aid, their balance-of-payments deficits would also be far smaller. Based on a comparison of these scenarios, Leontief concludes that:

> .$. the reallocation of economic resources arising from the kind of international arms-limitation agreement that has been suggested repeatedly, both formally and informally by individuals and organizations inside and outside the U. N., is by far the most promising of the three schemes for world economic development .71

Conclusions of UNIOWM

The results of these numerous UNIOWM scenarios suggest, in general, that the economic prospects of the resource-poor LDCs are not very optimistic. The growth rate targets of the U.N.'s Second Development Decade are insufficient to begin closing the income gaps between developed and developing regions when population increases are taken into consideration. The limits imposed by mineral resources, agriculture, and the environment are not insurmountable and could be overcome through appropriate policies and investments; but "the principal limits to sustained economic growth and accelerated development are political, social and institutional in character."Tz To achieve accelerated development, therefore, two general conditions are considered necessary:

- far-reaching internal reforms in the LDCs including often drastic changes in sociopolitical institutions and economic policies—between 30 and 40 percent of GNP 'must be used for capital investment, particularly in the agricultural and export sectors, and both equitable income redistribution and increased public-sector participation are needed to increase the effectiveness of these investments; and
- significant reforms in the international economic order, aimed at reducing the potentially large balance-of-payments deficits in the developing regions—stabilizing commodity markets, stimulating exports of manufactured goods from the LDCs, and increasing financial transfers from the developed regions and resource-rich LDCs.

Neither of these conditions, taken separately, is sufficient to ensure a favorable outcome: "Accelerated development leading to a substantial reduction of the income gap between the developing and the developed countries can only be achieved through a combination of both of these conditions."[73]

[71] Ibid., p. 231.

[72] Leontief, Carter, and Petri, op. cit., p. 48.
[73] Ibid., p. 11.

Global 2000—Entering the 21st Century

Global 2000 is a global modeling study, rather than a "global model" in the same sense that World 3, WIM, LAWM, or UNIOWM are. Its projections result not from a single, integrated model but rather from a collection of sectoral models, independently developed or adopted by various Federal agencies and other organizations, plus a number of projections based on analytical techniques other than computerized simulation models. Despite the very limited degree of interaction among the sectors and agencies, however, and despite the frequent lack of consistency in their various assumption and data bases, these sectoral "submodels" collectively provide the U.S. Government with the same type of projections that the other more integrated global models produce for their users.[74]

Origin and Purposes

Global 2000 was carried out by an interagency task force of the U.S. Government in response to a directive issued by former President Carter in his environmental message to Congress on May 23, 1977:

> Environmental problems do not stop at national boundaries. In the past decade, we and other nations have come to recognize the urgency of international efforts to protect our common environment.
>
> As part of this process, I am directing the Council on Environmental Quality and the Department of State, working in cooperation with . . . other appropriate agencies, to make a one-year study of the probable changes in the world's population, natural resources, and environment through the end of the century. This study will serve as the foundation of our longer-term planning. 's

This mandate, as interpreted by the Global 2000 task force, imposed dual objectives on the study: its purpose was not only to "identify [future] problems to which world attention must be directed," but also "to identify and strengthen the Government's capability for longer-term planning and analysis. "[76] The resulting report, released in July 1980, addressed both of these goals, although relying on the Government's existing capability may have detracted from the accuracy and usefulness of the resulting projections. According to a Science editorial:

> A reading of portions of the report produced after **3** years reveals more about the functioning of the federal government than it conveys new reliable information about the future of the world. "

Various Federal agencies are already conducting a considerable amount of long-term analysis and planning, and a number of them have the capability to produce projections based on extensive data bases and sophisticated sectoral models, many of them computerized. These existing tools and procedures (and the skilled personnel who use them) represent the "present foundation" of the Government's long-range global planning—they embody the assumptions on which current analysis is based, and they are actually being used as at least a partial basis for current planning and decision-making. As a result, the study plan chosen by the task force was "to develop trend projections using, to the fullest extent possible, the long-term global data and models routinely employed by the Federal agencies. "[78]

However, they found that "each agency has its own idiosyncratic way of projecting the future, " based on its individual planning requirements and area of responsibility .79 As a result, each agency's projections tend to focus on a single factor (such as population, food, or energy) without adequately considering the feedback involved in a system where these factors are interacting variables. Furthermore, although these separate projections "have generally been used by the Government and others as though they had been calculated on a mutually consistent basis, " the different agencies' models "were never designed to be used as part of an integrated, self-consistent system. "[80] This leads to one of the study's basic findings:

> To put it more simply, the analysis shows that the executive agencies of the U.S. Government are not now capable of presenting the President with internally consistent projections of world trends in population, resources, and the environment for the next two decades.[81]

Despite these deficiencies, Global 2000 presents the most comprehensive and consistent set of projections yet produced by the U.S. Government, and it represents the first attempt to make such

[74] Gerald O. Barney, study director, *The Global 2000 Report to the President: Entering the Twenty-first Century* (Washington, D. C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 3, pp. v-vi.

[75] Jimmy Carter, *The President's Environmental Program 1977* (Washington, D. C.: U.S. Government Printing Office, 1977), p. hi-l 1.

[76] Barney, *The Global 2000 Report to the President*, vol. 1, p. 6.

[77] Philip H, Abelson, "The Global 2000 Report," *Science*, vol. 209, No. 4458, Aug. 15, 1980, p. 761.

[78] *The Global 2000 Report to the President*, vol. 1, p. 6.

[79] Ibid., vol. 2, p. 454.

[80] Ibid.

[81] Ibid.

projections on a coordinated, integrated basis. The task force has been disarmingly frank and forthcoming in their analysis of "the Government's global model," and their discussion of its current weaknesses points to a number of ways in which existing long-range analysis and planning tools can be improved. Several of the models have in fact been modified or expanded in the last 3 years, often in response to problems identified by the task force, although many problems still remain.[82] The task force cautions, however, that "in the absence of ongoing institutional incentives to address cross-sectional interactions, the present form of the government's global model is not likely to change significantly in the foreseeable future."[83]

Structure and Assumptions

For the purposes of Global 2000, the study team imposed a "special limited discipline," within the time and resource constraints of the study, under which: 1) the assumptions, structures, and projections of the agencies' sectoral submodels were made "more mutually consistent" and 2) the output from one sector was used as the input for another "whenever this was readily feasible."[84] Despite these efforts, however, the Government's model has almost no feedback loops and remains at best "quasi-integrated," with the result that, "if anything, the severity of the effects of these basic trends may be understated."[85] In addition, the submodels employ different patterns of regionalization, varying from as few as five to as many as 28 regions, with a similar variation in the degree of detail provided.[86] This not only makes coordination difficult but also leaves the projections without a consistent geographic reference for policy analysis.

Furthermore, there are numerous major inconsistencies in the values assigned to the same variable in different sectoral submodels, reflecting mutually contradictory agency assumptions about the behavior of crucial factors.[87] The population sector, for example, assumes that birth rates in LDCs will decline because of continued moderate socioeconomic development, whereas the agricultural and economic projections indicate only marginal increases in global food and GNP per capita, with real declines in some LDCs—hardly reflecting moderate socioeconomic development.[88] Similarly, the GNP submodel assumes that the real price of wheat will *decrease* by 0.6 percent per year and that the real price of oil will remain constant during the early 1980's, whereas the food and energy projections indicate real price increases of 2.1 and 5.0 percent per year, respectively, over roughly the same period.

Far more serious, however, is the absence of any consistent accounting of capital or resource allocations in any of the sectoral submodels. This leads to what the report calls "significant omissions and double-counting'–in effect, the model recognizes no conflicts from competing demands or uses, and it places no constraints on the amount of capital and resources available to each sector.[89] Under these conditions, the same acre-foot of water is assumed to be available for both irrigation and energy development, just as the same barrel of oil is assumed to be available for transportation, energy generation, and petrochemical feedstock.

Different sectors also contain contrasting or contradictory assumptions about the course of public policy, despite the report's frequent repetition of the caveat that its trend projections are made *"under the assumption that present policies and policy trends continue without major change."*[90] The most significant exception to this rule comes in the population projections, which are based on the assumptions of: 1) continued socioeconomic progress despite marginal gains in food and GNP per capita in the LDCs; and 2) adoption of family planning policies in all countries and major extensions of existing programs, especially in rural areas. The other sectoral projections, however, are based on equally significant policy assumptions, including the following:[91]

[82] Ibid., vol. 2, p. 460 n. 2.
[83] Ibid., vol. 2, p. 461.
[84] Ibid., vol. 2, p. 457.
[85] Ibid., vol. 2, pp. 456, 481.
[86] Ibid., vol. 2, pp. 485 n. 1, 478; see also table 14-3, p. 479, and the methodological maps following p. 442.

[87] Ibid., vol. 2, pp. 461-476; see also table 14-2 and pp. 470-475 for an extensive discussion of "selected contrasting assumptions."
[88] Ibid., vol. 2, pp. 481-482.
[89] Ibid., vol. 2, p. 467.
[90] Ibid., vol. 2, p. 3; emphasis theirs.
[91] Ibid., vol. 2, table 14-2 and pp. 470-475; see also pp. 485-499.

- GNP.—Implementation of "prudent" policies to maximize export earnings, with GNP growth in the LDCs largely dependent on GNP growth in the developed regions;
- Food.—Major public and private investments in land development; a worldwide shift toward more fossil-fuel-intensive agricultural techniques and inputs; and (implicitly) improved resource management to protect fisheries and to prevent overgrazing, erosion, and farmland degradation;
- Energy.–Widespread deployment of light-water nuclear electric powerplants; implementation of more effective energy conservation programs in OECD countries; willingness of OPEC countries to meet oil demand up to their maximum production capacity; and major public and private investment in air pollution abatement so that by 1985 all countries' energy facilities are retrofitted to meet U.S. new-source performance standards for CO, SO_x, NO_x, and particulate; and
- Technology.–Major technological progress in almost 'all sectors, with no 'technological setbacks or adverse side effects; and extensive worldwide transfer and deployment of family-planning, yield-enhancing, nuclear-power, and pollution-abatement technologies.

In addition, the "no-policy-change" assumption itself explicitly excludes the possibility of either planned change or sudden upheaval in the world's existing political institutions and economic arrangements:

> . . . the Study assumes that there will be no major disruptions of international trade as a result of war, disturbance of the international monetary system, or political disruption. The findings of the Study do, however, point to increasing potential for international conflict and increasing stress on international financial arrangements. Should wars or a significant disturbance of the international monetary system occur, the projected trends would be altered in unpredictable ways.[92]

Findings and Conclusions of Global 2000

In the absence of more extensive policy testing, and because of the presence of contradictory and often controversial policy assumptions, Global 2000 does not provide an adequate basis for coordinated analysis or detailed policy recommendations. Furthermore, because of the omissions and inconsistencies outlined above, the study team concludes "that it is impossible to assign a high probability to any of the specific numeric projections presented" for its different sectors.[93] However, the current weaknesses and deficiencies of "the Government's global model" do not necessarily or completely invalidate its overall results, and the study team concludes that "these basic findings are qualitatively correct," since they are in general agreement with past projections by the same agencies, are supported collaterally by the alternative sectoral projections of outside organizations, and correspond "in . . . their most basic thrusts" with projections generated by "less complex but more highly integrated global models."[94]

Global 2000's often-quoted general conclusions about the future are as follows:

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutionary advances in technology, life for most people on earth will be more precarious in 2000 than it is now—unless the nations of the world act decisively to alter current trends.[95]

The principal sectoral findings on which these general conclusions are based, briefly outlined, are as follows:

- Population.—Global population growth rates will not decline significantly by 2000 and, in absolute terms, net population growth will be faster than it is today. The world's total population will increase by 55 percent, from 4.1 billion in 1975 to 6.35 billion in 2000, with 92 percent of the growth occurring in the LDCs, particularly in Africa and Latin America.

[92] Ibid., vol. 1, pp. 7-8.

[93] Ibid., vol. 2, p. 481.

[94] Ibid.

[95] Ibid., vol. 1, p. 1.

- GNP.—Worldwide GNP is projected to increase 145 percent during the 1975-2000 period, with faster annual growth in the LDCs (4.5 percent) than in the developed nations (3.3 percent), although growth rates in all regions will decline after 1985. Due to differential population growth, however, GNP per capita will grow much more slowly—an overall increase of only 53 percent worldwide, with marginal improvements or actual declines in a number of LDCs in Africa and South Asia. Existing income disparities between the richest and poorest nations will widen, and "dramatically different rates of change would be needed to reduce the gap significantly by the end of the century. "[96]
- Food.—Worldwide food production is projected to increase by 2.2 percent annually from 1970 to 2000, a rate approximating the record increases of the Green Revolution. Since most of the good arable land is already under cultivation, most of this increase will come from more intensive use of energy-intensive inputs and technologies, resulting in an increased dependence on oil and gas and at least a doubling of real food prices by the end of the century. Since food production grows more rapidly than population, average per capita consumption will increase 15 percent worldwide by 2000, but with significant regional variations—increases of 21 percent in the developed regions but only 9 percent in the LDCs, with smaller increases in North Africa, the Middle East, and South Asia; and a "calamitous" 19. l-percent decline in Central Africa, where average caloric intake is already well below the minimum requirements set by the U.N. Food and Agriculture Organization. These projections suggest the need for food imports and food assistance will continue to grow in the developing regions, particularly in the poorest countries.
- Energy .-The energy projections, made in late 1977, indicate that world energy demand will increase 58 percent over the 1975-90 period. However, petroleum production capacity is not increasing as rapidly as demand, and the rate of reserve additions per unit of exploratory effort appears to be declining. As a result, technical considerations indicate that petroleum production will peak before the end of the century, although political and economic decisions by OPEC countries could cause production to level off even earlier. The resulting transition away from petroleum dependence is projected to be led by nuclear and renewable sources (primarily nuclear, but including hydro, solar, and geothermal), which are forecast to increase 226 percent by 1990; production of petroleum, natural gas, and coal is projected to increase by 58, 43, and 13 percent, respectively, over the same period. The projections also indicate considerable potential for reducing energy consumption per unit of economic production.
- Resource prices.–Global 2000 finds that the real prices of food, fish, lumber, water, and energy will increase significantly by 2000, with the steepest increases occurring after 1985. However, this finding shows how the nonintegrated model can lead to an economic paradox:

  > If the real prices of these commodities increase as projected, for what corresponding commodities will real prices decrease? If no compensating real-price decreases are projected, what do these "real" price increases mean theoretically—or even semantically? Unfortunately, even attempting to develop answers to these difficult questions would have exceeded the time and resource constraints of the study .[97]

- Environment.–Major strains will be placed on ecological systems throughout the world, leading to significant deterioration in terrestrial, aquatic, and atmospheric resources that would have adverse impacts on agricultural productivity, human mortality, and economic development. There are already signs of many of these effects, which will be felt more strongly, particularly in the LDCs, toward the end of the century. The projected increase in fossil fuel combustion could be expected to double the CO_2 content of the atmosphere by 2050, leading to a 2° to 3° C rise in temperatures and significant alterations in weather and precipitation patterns in the temperate zones,

[96]Ibid. vol 1 p. 13; compare with the discussion of UNIOWM, above.

[97]Ibid., vol. 2, p. 480 n. 1

where most of the world's food-exporting nations are located.

- Species extinctions.—Between 0.5 million and 2.0 million species of plants and animals could be extinguished by 2000, mainly through the loss of wild habitats or through pollution. This threat is particularly great in the tropical forests, which are an important potential source of new foods, pharmaceuticals, and building materials. An equally important threat is posed by the possible loss of local and wild varieties that are needed to breed pest-and disease-resistant traits into high-yield cereal grains.

Updates of these projections, developed on the basis of subsequent events or improvements in the forecasting tools, generally support the initial findings of Global 2000 and, if anything, provide even less reason for optimism:

- Fertility rates have declined more rapidly than expected in some areas, but world population in 2000 will be only 3 percent lower than originally projected.
- GNP projections are somewhat lower, due to increased petroleum prices and efforts to control inflation in OECD countries, with a consequent drop in LDC growth rates.
- Agricultural projections have also been revised downward, due to rapid increases in energy-related production costs and diminishing returns for other yield-enhancing inputs. In addition, increased concern with the consequences of intensive cultivation has led (in the United States and other developed nations) to pressure for resource-management policies that would prevent further erosion and soil deterioration. Some LDC governments are intervening in domestic markets to keep food prices low, often to the detriment of rural development and production capacity.
- The greatest differences are found in the energy sector: updated projections, reflecting the sudden large increase in oil prices in 1979, show that demand will be lower due to higher prices and slower economic growth caused by energy impacts in other sectors. Estimates of maximum OPEC production levels are lower, reflecting the cartel's resource-conservation policies. Estimates of future OECD nuclear capacity are also lower, reflecting construction delays and public concern as well as the U.S. licensing moratorium, and coal is projected to provide a larger share of energy supplies. Higher prices are also expected to encourage the adoption of alternative sources (including solar) and conservation measures.