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LIMITS TO GROWTH REVISITED: HAS THE WORLD MODELING DEBATE MADE ANY PROGRESS?

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LIMITS TO GROWTH,[1] one of the most controversial academic studies of this century, was introduced to the world on March 2, 1972, at the Smithsonian Institution in Washington, D.C. Written by Dennis Meadows and others at the Massachusetts Institute of Technology, this study was released amid great publicity and interest. The immediate reaction came primarily in the popular press, which focused on the book's dire predictions of future world collapse. The media speculated that this study might change the course of mankind, was an international event, contained chilling statistics to underscore man's predicament, was a pioneering effort towards planetary planning, raised life-and-death questions, and should stir the imagination of thoughtful men and women everywhere.

Severe criticism was also immediately leveled at every aspect of the study. Some of this criticism was reported in the popular press, but the majority of adverse reaction came more slowly in the academic journals and specialized publications. The criticism was intense and broad-ranging. The study was claimed to be a piece of irresponsible nonsense, wolf crying; over-simplified and confusing, a doomsday prophesy, and a publicity stunt. Serious doubts were expressed about the validity of its assumptions. The methodology of the model was also felt to be uncomfortably similar to the authors' subjective preconceptions.

At present the LIMITS debate continues to simmer at a less visable level as opposing sides dig in for a prolonged fight. The depth of feeling remains intense but the arena has shifted from the popular press to scientific meetings, journals, and counter-modeling efforts.

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[1] D.H. MEADOWS, *et al.*, LIMITS TO GROWTH (1972) [hereinafter cited as LIMITS].

While this departure from the public spotlight is inevitable, it is perhaps unfortunate since the debate raised by the study and its outcome may be crucial to predicting and controlling the world's future. Further, without a broad public grasp of the conclusions to this debate, there will be little hope that social and political policies designed to avoid possible adverse consequences can be instituted or sustained in any peaceful or democratic manner. Some commentators doubt the feasibility of this latter climate for change, regardless of the public's grasp of the situation.[2] It is certain, however, that unless people can comprehend the consequences of their actions, voluntary changes in behavior or attitudes will be impossible.

In the spirit of broadening the range of participants in the continuing debate over prospects for the world's future, this article provides a survey of recent world models and evaluates them. The critical responses to these models trace a dialog of immense importance to the way in which global problems will be dealt with in the future. The modeling tools being researched and debated today will surely become important forms of analysis for policy makers within the next decade. In turn, the accuracy of the assumptions upon which these modeling tools are based and the success with which they are applied will significantly affect the direction of world events.

I. Origins Of The Global Models

The existence of the world models which form the basis of the Limits To Growth controversy was dependent upon two separate but parallel developments. First, a method of modeling complex systems, *system dynamics*, had to be developed and the large computers capable of running such massive models had to be perfected. Second, support for the application of such tools to world problems had to mature. These two developments merged on June 29-30, 1970, when Professor Jay W. Forrester of the Massachusetts Institute of Technology was invited to address a meeting of the Club of Rome in Bern, Switzerland. From this meeting emerged a series of world models. In order to better understand these models, it is necessary to look briefly at the background both of Forrester's *system dynamics* and of the Club of Rome. Following this examination, the events leading up to and surrounding the public presentation of the Limits To Growth results in March, 1972, will be described.

[2] *See generally* R.L. Heilbroner, An Inquiry into the Human Prospect (1974) and R. Vacca, The Coming Dark Age (1974).

A. *System Dynamics*

Computer models attempt to make explicit the myriad of relationships affecting a designated system or set of interrelated forces. In a sense, they attempt to imitate mental models of such systems. Computer models, however, unlike mental models, can explicitly and sequentially show dynamic consequences as components of the system interact. This capability makes possible analysis of the interactions in a manner which would be difficult, if not impossible, with mental models. Jay W. Forrester pioneered the application of the digital computer, tactical military decision-making, and information-feedback systems to the interacting forces of social systems. His experience in the late 1940's and early 1950's designing air defense systems and guiding the production of their needed components led to an approach to management problems which differed considerably from previous attempts. Starting at M.I.T. in 1956, he refined this analysis of industrial problems, resulting in the first publications on industrial dynamics as a management technique later in the decade[3] and the appearance of his book, INDUSTRIAL DYNAMICS, in 1961.[4]

The approach to modeling an industry is similar to that dealing with other complex systems under the *system dynamics* methodology. Basically, it is necessary to build models by precisely describing the system organization, its internal relations, and assumptions about external contacts across the system boundary. This approach depicts the effect of various influences on the growth and change of the system. It is possible, as a next step, to change components or relationships in order to simulate alternative outcomes. Such *gaming* becomes valuable because, while managers can describe their organization and its relationships, they cannot intuitively grasp the dynamic behavior of the organization. Thus, according to *system dynamics*, mental models are inferior to computer models because only computer models enable interrelationships and their consequences to be made explicit. While this technique is only as good as the soundness of the relationships built into the model, it has proven valuable to management science in many cases.[5]

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[3] *See* Forrester, *Industrial Dynamics—A Major Breakthrough for Decision Makers*, 36 HARVARD BUSINESS REVIEW 37-66 (1958); Forrester, *Advertising: A Problem in Industrial Dynamics*, 37 HARVARD BUSINESS REVIEW 100-10 (1959).

[4] J.W. FORRESTER, INDUSTRIAL DYNAMICS (1961). The technique of *system dynamics* is covered in: J.W. FORRESTER, PRINCIPLES OF SYSTEMS: TEXT AND WORKBOOK (1968) and extended by M.R. GOODMAN, STUDY NOTES IN SYSTEM DYNAMICS (1974).

[5] For applications and critical review of *system dynamics* as applied to industry, *see* Ansoff

After applying *system dynamics* to industrial cases, Forrester began modeling urban areas. It was found again that managers could describe their systems but not predict behavior. Not only were systems *counter-intuitive*,[6] but also nearly every measure in urban areas which alleviated a problem in the short-run was found to be detrimental in the long-run. The results of this extension of systems modeling were published in 1969 as URBAN DYNAMICS,[7] providing a computer model of the major internal forces affecting the balance of urban population, housing, and industry. The work in urban dynamics was extended in later years as applications and criticisms took place.[8]

Forrester's *system dynamics* thus had nearly fifteen years of development behind it at the time that the Club of Rome became interested in it.[9] While this technique has been severely criticized,[10] particularly because many relationships in previous applications were put into equations without the benefit of sufficient empirical data, it is presumably capable of intuitively sorting out complex interactions and simulating their possible outcomes. Club of Rome members wanted to apply this type of activity to a situation which they termed *The Predicament of Mankind*.

B. Club of Rome

One man was essentially responsible for the existence of the LIMITS TO GROWTH study. Utilizing perseverence, patience, and considerable financial backing, Dr. Aurelio Peccei pursued activities and studies leading to LIMITS TO GROWTH. Dr. Peccei's efforts took concrete shape as the Club of Rome, an organization which in turn

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and Slevin, *An Appreciation of Industrial Dynamics*, 14 MANAGEMENT SCIENCE 383-97 (1968); Forrester, *Industrial Dynamics: After the First Decade*, 14 MANAGEMENT SCIENCE 398-415 (1968); D.L. MEADOWS, DYNAMICS OF COMMODITY PRODUCTION CYCLES (1970); H.S.D. COLE, *et al.*, MODELS OF DOOM (1973) [hereinafter cites as DOOM]; Coyle, *On the Scope and Purpose of Industrial Dynamics*, 4 INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE 397-406 (1973); Coyle, *System Dynamics: An Approach to Policy Formulation*, 73 JOURNAL OF BUSINESS POLICY 40-48 (1973).

[6] Forrester, *Counterintuitive Behavior of Social Systems*, 73 TECHNOLOGY REVIEW 1-14 (1971).

[7] J.W. FORRESTER, URBAN DYNAMICS (1969).

[8] For critical reviews of urban applications of *system dynamics*, *see* READINGS IN URBAN DYNAMICS: VOLUME I (N.J. Mass ed. 1974).

[9] For an overview of Forrester's work on *system dynamics* applied to industrial and urban problems, *see* COLLECTED PAPERS OF JAY W. FORRESTER (J.W. Forrester ed. 1974).

[10] A flavor of the criticism engendered by *system dynamics* applications is shown by Schwartz and Foin, *A Critical Review of the Social Systems Models of Jay Forrester*, 1 HUMAN ECOLOGY 1-13 (1972).

provided the incentive and financial backing for a world model to explore critical problems and to suggest solutions. Controversial and energetic, Peccei convinced others that his concern about the world's future should be converted into concrete action aimed at finding solutions.[11]

In the mid-1960's, Peccei first began to realize that world problems were embodied in a set of interconnected relationships and could only be comprehended through an overview that explicitly provided the links between seemingly unrelated occurrences and conditions. He viewed the world as basically mismanaged. Accustomed to rational management of comprehensible business and engineering systems by technicians and experts, Peccei set out to pursue a similar approach to and solution for world problems. In THE CHASM AHEAD,[12] Peccei described his erratic support of a study to explore possible solutions.

During 1968 he joined with other individuals who shared his opinion about the state of world problems to form the Club of Rome in order to pursue, in a more organized manner, solutions to these pressing phenomena. By 1970 the Club had grown to 75 members of 25 nationalities. The image of a project concerning *The Predicament of Mankind* gradually took shape and encompassed many of the ideas first expressed in THE CHASM AHEAD.[13]

C. *Birth of a World Model*

Jay W. Forrester presented one possible methodology, *system dynamics*, for studying *The Predicament of Mankind* and possible transitions to global equilibrium at the June 29, 1970, meeting of the Club in Bern, Switzerland. Forrester felt that *system dynamics* could ". . . deal with the broad sweep of human affairs and the way in which major elements of the world ecology interact with each other."[14] One result of this meeting was Forrester's invitation for

[11] For background information on Peccei, *see* Northrup, *Club of Rome Merges World's Woes Into One - And Tries to Solve It*, Wall Street Journal, October 2, 1972, reprinted as Northrup, *Club of Rome - 75 Powerful Men Who Want to Save the World*, 73 SCIENCE DIGEST 22-25 (March 1973); Simmons, *System Dynamics and Technocracy*, in DOOM, *supra* note 5, at 205-06; A. PECCEI, THE CHASM AHEAD (1969) [hereinafter cited as CHASM]; *The Club of Rome's Co-founder*, 72 NEW SCIENTIST 604 (March 16, 1972).

[12] CHASM, *supra* note 11.

[13] For more information on the Club of Rome, *see* Peccei, *The Predicament of Mankind*, 70 SUCCESSO 149 (June 1970); Peccei, *Where Are We? Where Are We Going?* 70 SUCCESSO 119-26 (February 1970); Kind, *The Totality of the World Problematique Must Now Be Addressed*, 5 CENTER REPORT 29 (October 1972); *Club of Rome: A Worldwide Organization*, New York Times, March 1, 1972, at 38, col. 3.

[14] J.W. FORRESTER, WORLD DYNAMICS (1972) [hereinafter cited as WORLD DYNAMICS].

Club members to visit M.I.T. to determine "firsthand" if *system dynamics* methods were suitable for pursuing the "project."

Forrester perfected his beginnings of a "world model" (*World:1*) into a dynamic set of interactions expressed in *system dynamics* format early in July, 1970. On July 20, 1970, the Club convened in Cambridge, Massachusetts for ten days of study, presentations, and discussion concerning *World:1*. As a result of the Cambridge meeting, the Executive Committee of the Club established a one-year $250,000 research program at M.I.T. with funding by the Volkswagen Foundation in Germany. This initial study, *Phase One of the Project on the Predicament of Mankind* (*Phase One*) was conducted by an international team under the direction of Professor Dennis Meadows, a colleague of Forrester's at M.I.T.

Forrester did not participate directly in *Phase One*, but did pursue the world model which he had prepared for the July, 1970, meeting. He quickly expanded the computer model used at the July, 1970 meeting into a manuscript describing his world *system dynamics* model in full detail and discussing possible future outcome of policy alternatives. This formulation came to be known as the *World:2* model.

World:2 sketched a world system with five variables: world population, natural resources, industrial capital, agricultural capital, and pollution. Each of these variables, except natural resources, has both an inflow and an outflow affecting the amount (level) of the variable, such as births and deaths for population level or investment and deterioration for capital. Only natural resources lack an inflow because of the posited irreplaceable nature of resource stocks. These flows affect the levels of variables and are related to each other and to the levels of variables by equations describing, empirically and intuitively, the interrelationships. The intuitive relationships especially, but also the empirical relationships, are tested for viability by running the model from 1900 to 1970 to ensure that they follow historical patterns. Then various policies can be simulated so that their likely results in the future, up to the year 2100, can be determined.

Forrester was careful to qualify his goals in developing *World:2* and in communicating *World:2* via his book, WORLD DYNAMICS. He looked only at broad aspects of the world system and did not address the difficulties of implementing changes needed to alter the course of human events. He did not allow for the changes in human aspirations and values that could accrue from widespread recognition of

the predicament facing mankind.[15] Rather, he placed his own confidence in this simplistic sketch of the world's dynamic behavior as a source of recommendations for action and challenged others to counter his image of the world's future with explicit responses.[16]

Despite Forrester's qualifications and limitations on the relationship of his model to the real world, he came under immediate attack for nearly every aspect of WORLD DYNAMICS. However, this criticism appeared primarily in the scientific journals. If the public was aware of the study at all, it was aware only to the extent of a vague impression that a computer model had found disquieting evidence about future world conditions. This low-level public exposure would not be repeated in the next round of global modeling.

The Club of Rome's *Phase One* study started in the fall of 1970 and was completed in eighteen months. Forrester's *World:2* model gave the international team of seventeen a running start for their work. Basically, the WORLD DYNAMICS model was extended and disaggregated into separate sectors by the Meadows' group, thereafter becoming known as the *World:3* model. By the summer of 1971, the work at M.I.T. was progressing well. At the time WORLD DYNAMICS was published, Dennis Meadows was ready to discuss the preliminary findings of *Phase One*. In the process of revising the original Forrester model and verifying its conclusions, the M.I.T. group generated a series of "working papers."[17] None of the alterations made by the group had resulted in ". . . any major differences to the crisis forecasts or the crisis measures needed to avoid them."[18] Thus, the M.I.T. group could join the Club of Rome as early as the summer of 1971 in ". . . urgently contacting decision-makers up to the head of state level to warn them where their present policies might be leading."[19]

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[15] *Id.*, at ix.

[16] In Forrester's words:

> Having defined with care the model contained herein, and having examined its dynamic behavior and implications, I have greater confidence in this world system model than in others that I now have available. Therefore, this is the model I should use for recommending actions. . . . It is to be hoped that those who believe they already have some different model that is more valid will present it in the same explicit detail, so that its assumptions and consequences can be examined and compared . . . .

Id.

[17] The major papers were listed in an "Appendix—Related Studies," LIMITS, *supra* note 1, at 198-200. These papers were published in TOWARD GLOBAL EQUILIBRIUM: COLLECTED PAPERS (D.L. Meadows & D.H. Meadows eds. 1973).

[18] Leach, *Computer Warns of World Pollution Fight Errors*, Denver Post, July 19, 1971, at 18. *See also* Meadows, *Predicament of Mankind*, 71 FUTURIST (August 1971), reprinted in: 133 CURRENT 3-9 (October 1971).

[19] Leach, *Computer Warns of Pollution Fight Errors*, *supra* note 18.

A preliminary draft report on the results of the M.I.T. group's efforts, based largely on the "working papers," and entitled LIMITS TO GROWTH (LIMITS) was scheduled for publication in March, 1972.[20] Various members of the Club of Rome did not wait until publication to talk about the book's results. Thus, the press picked up hints that a major computer study of global trends predicted dire consequences for mankind unless radical changes were instituted.[21] The apparent importance of the study's findings was enhanced by indications that LIMITS TO GROWTH was being "polished and refined" by Potomac Associates, a newly formed research organization, and would be translated into a dozen languages by the Club of Rome and placed in the "right" hands so that its message could influence policy and stir public debate.[22]

In preparation for release of the book, Potomac Associates hired a public relations firm which prepared appropriate press releases and background materials. The public relations campaign culminated on February 27, 1972, and resulted in widespread newspaper coverage.[23] As an appropriate "birth" for LIMITS TO GROWTH, Potomac Associates had been able to arrange for the Woodrow Wilson International Center For Scholars at the Smithsonian Institution in Washington to hold a "Symposium" on March 2, 1972, financed by the Xerox Corporation. This invitation-only affair was blown into a major event by the publicity and the desire of distinguished individuals of all professions to attend. By March 2, when copies of LIMITS reached the bookstands, the publicity efforts of Potomac Associates, the Club of Rome, and the M.I.T. group had turned the presentation into a major production for the 250 guests and assorted media.[24] The Club's major program of translation and distribution further guaranteed wide attention.

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[20] The preliminary draft report on *Phase One* was written by Dennis Meadows' wife Donella, also a member of the study team at M.I.T. It was circulated to a number of people during the fall of 1971, with a copy reaching a newly formed "non-partisan research and analysis organization" called Potomac Associates. The rights to publication of a *Phase One* report for "general readership" were signed over to this group late in 1971. Subsequently, Potomac Associates hired an editor and illustrator to rework Donella Meadows' draft report. Gillette, *The Limits to Growth: Hard Sell for a Computer View of Doomsday*, 175 SCIENCE 1089 (March 10, 1972) [hereinafter cited as *Hard Sell*].

[21] *The Worst Is Yet To Be?* TIME, January 24, 1972, at 32; Lewis, *To Grow and To Die*, New York Times, January 29, 1972 at 29, col. 1; Lewis, *To Grow and To Die: II*, New York Times, January 31, 1972 at 41, col. 1.

[22] *The Worst Is Yet To Be?, supra* note 21.

[23] Reinhold, *Mankind Warned of Perils in Growth*, New York Times, February 27, 1972 at 1, col. 5.

[24] *Hard Sell, supra* note 20, at 1088-92.

At the Symposium, Meadows described the major findings of LIMITS, followed by some general discussion which can be seen in retrospect as the opening salvo of intense criticism of the study and its findings and recommendations.[25] The contrast between the public debut of LIMITS and of WORLD DYNAMICS was striking. The pitch of LIMITS at general readership and the blitz of publicity made it an international event whereas WORLD DYNAMICS reached few ears, even though its essential structure and conclusions were exactly the same as those of LIMITS.

II. THE LIMITS MODEL AND ITS PREDICTIONS

Both supporters and critics of the analysis contained in LIMITS TO GROWTH agree that such analysis represented one of the most ambitious attempts to date to bring together the interaction of five global variables (population growth, non-renewable resource depletion, food supply, capital investment, and pollution) into one general model of the future of the world.[26] The ambitiousness of LIMITS was pointed out by its authors:

> The model we have constructed is, like every other model, imperfect, over-simplified, and unfinished. We are well aware of its shortcomings, but we believe that it is the most useful model now available for dealing with problems far out on the space-time graph. To our knowledge it is the only formal model in existence that is truly global in scope, that has a time horizon longer than thirty years, and that includes important variables such as population, food production, and pollution, not as independent entities, but as dynamically interacting elements, as they are in the real world.[27]

Many could not comprehend the purpose of the authors as to timing and format of the report. This confusion or disagreement interfered with the message which the authors desired to convey.

For example, their choice of early publication of results became one area of bitter dispute over LIMITS.[28] A basic belief of the *system dynamics* school is that decisions are constantly being made on important matters affecting the future, with only the help of mental

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[25] Reinhold, *Warning on Growth Perils Is Examined at Symposium*, New York Times, March 3, 1972 at 41, col. 6.

[26] Even one of the severest critics admits that ". . . it is one of the most original and ambitious constructions in the history of social science." Freeman, *Malthus With a Computer*, DOOM, *supra* note 5, at 10.

[27] LIMITS, *supra* note 1, at 21-22.

[28] For example, *see Another Whiff of Doomsday*, 236 NATURE 47-49 (March 10, 1972); *Limits to Misconception*, THE ECONOMIST, March 11, 1972, at 20-22.

models. More precision and intuition can be reached with the help of explicit mathematical models, such as *World:3*. A belief in the representativeness of *World:3* as a functional model of the world meant that it had reached a stage of usefulness in the authors' eyes: ". . . the basic behavior modes we have already observed in this model appear to be so fundamental and general that we do not expect our broad conclusions to be substantially altered by further revisions."[29]

Even if the authors firmly believed in the usefulness of *World:3* as a guide to policy makers, their choice of the LIMITS TO GROWTH format remained a puzzle to many readers. The authors and their supporters believed that a non-technical summary of the meaning and consequences of *World:3* was too important and urgent to be left only within technical, scientific circles. They believed that LIMITS' meaning and message should quickly be brought to a wider public.[30] It was decided that the complete, scientific description of all the data and mathematical equations included in *World:3* would not be published until release of the final technical report,[31] although a few groups of critics were given access to drafts of the technical report earlier.[32] This unorthodox approach to publication of a scientific study diluted the impact of the study's findings in some scientific circles.[33]

A. An Explicit Description of Man's Predicament

The Predicament of Mankind, which had been the subject matter of the M.I.T. *Phase One* study, could now be expressed in more concrete terms. One conclusion reached by the group was expressed in the Introduction of LIMITS thusly:

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.[34]

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[29] LIMITS, *supra* note 1, at 22.

[30] *Id.* at 23.

[31] Despite promises that the technical report would "shortly" be available to the general public, it took over two and one-half years before it was released. DYNAMICS OF GROWTH IN A FINITE WORLD (D.L. Meadows & D.H. Meadows eds. 1974).

[32] Only by making preliminary copies available to a few groups of critics was it possible to have timely rebuttal of LIMITS. A prime example of such dialogue was DOOM, *supra* note 5.

[33] *See infra* note 58.

[34] LIMITS, *supra* note 1, at 23.

These growth trends, as well as the limits to their continuation, were summarized as "The Limits To Exponential Growth."[35]

The "most probable" scenario of rather abrupt and uncontrolled decreases in population and output was highlighted by a "World Model Standard Run,"[36] which simulated conditions to the year 2100, assuming the occurrence of ". . . no major change in the physical, economic, or social relationships that have historically governed the development of the world system."[37] In this computer run, the five basic variables followed historical values from 1900 to 1970. After 1970, food, industrial output, and population grow exponentially until a rapidly diminishing resource base slows down industrial growth. Natural delays cause population and pollution to continue growing beyond the peak of industrialization. Population is finally halted by decreasing food and medical services which jointly boost the death rate.[38] This behavior mode is overshoot and collapse, with the consequence that growth is stopped well before the year 2100.

Perhaps even more discouraging, the authors found that not even the "most optimistic" estimates of the benefits of technology could postpone the collapse beyond the year 2100 A.D. This conclusion was reached by a series of modified runs of the world model to test the impact of alternative assumptions about the behavior of variables. In each case exponential growth of population and capital occurred, followed by collapse.[39] The authors concluded that:

> . . . technological optimism is the most common and the most dangerous reaction to our findings from the world model. Technology can relieve the symptoms of a problem without affecting the underlying causes. Faith in technology as the ultimate solution to all problems can thus divert our attention from the most fundamental problem—the problem of growth in a finite system—and prevent us from taking effective action to solve it.[40]

This was not a blanket rejection of technology, but rather a call for its selective adaptation within a world determined to provide deliberate checks on further growth.

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[35] *Id.* at 45-87.
[36] *Id.* at 124-25.
[37] *Id.* at 124.
[38] *Id.*
[39] *See* "Chapter IV — Technology and the Limits to Growth," *id.* at 129-55.
[40] *Id.* at 154.

B. Interaction Among the Five Global Variables

LIMITS provides a summary amount of detail on each of the five variables and their interactions within the global system. Population is currently rising exponentially and will double in thirty-two years, with successive doubling predicted at an even more rapid rate.[41] Land is an essential input to food and, despite a doubling or even quadrupling of food output per acre, a food shortage will be inevitable.[42] Other necessary prerequisites to continued growth will also become scarce. Minerals and fossil fuels have limited, even if presently unknown, reserves, and they will become progressively more expensive and scarce in spite of technological advancements and discoveries.[43] The existence of an ecological system, within which man must derive his sustenance, dictates limits to man's transformation of his surroundings. Heat dissipation, disposal of radioactive and toxic chemical wastes, reduction in the number of living species, and many other interactions between man and his environment must ultimately be constrained in some manner such that this "spaceship earth" will continue to support human life.[44]

Currently, growth of population and production means concomitant growth of environmental pollution.[45] This adverse environmental impact, if projected into the future, also provides a limiting factor on future growth. As pessimistic as any one of these trends appears to be for the world's future, it is their interaction which the report considers deadly. By a phenomenon known as feedback, one variable's growth accentuates problems in other areas.[46] Population growth necessitates additional food, but advances in food production may require exploitation of non-renewable resources and result in additional pollution. Eventually each variable acts as a limiting factor on the others: high levels of pollution may limit food supplies and endanger human beings; dwindling resources may limit growth of production and thereby decrease world income; large populations may decrease each individual's opportunities for diversity and material comfort.

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[41] *Id.* at 25-44.
[42] *Id.* at 46-54.
[43] *Id.* at 54-69.
[44] *Id.* at 85.
[45] *Id.* at 69-81.
[46] *See* "Chapter I — The Nature of Exponential Growth," *id.* at 25-44.

C. *Suggested Policies and Initial Reactions to the* World:3 *Model*

LIMITS could truly be labelled a harbinger of doom were it not for the fact that the authors attempted to define conditions whereby the consequences of overshoot and collapse could be avoided. Through simulation of alternative conditions, it was possible to find sets of variable relationships that were "viable" over the long run. The goal was to attain sustainable relationships between variables that would be capable of satisfying the basic material requirements of all the world's population without sudden and uncontrollable collapse.[47] The attainment of this goal required constant levels of population and capital, a condition termed *global equilibrium*.[48] In the view of the authors: "The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his individual human potential."[49]

By further specifying a long time horizon for the existence of global equilibrium and long average lifetimes for the population, it was possible to work back to a set of "minimum" requirements necessary to reach a state of global equilibrium. These requirements included: 1) capital plant and population held at a constant size; 2) all input and output rates—births, deaths, investment, and depreciation—kept to a minimum; 3) levels of capital and population as well as the ratio of the two, set in accordance with the values of society.[50] A scenario compatible with these requirements involves a stability in growth of population and industrial capital prior to the end of this century, a large decrease in use of resources from production and its reorientation toward services and food, and a massive reduction of pollution generated by industry and agriculture.

LIMITS insists that such a global equilibrium does not mean stagnation, since population and capital are the only quantities that must be constant in the equilibrium state. Activities which do not require large amounts of irreplaceable resources or produce environmental degradation could continue, although most present industrial processes and products would require considerable transformation or elimination. Technology of a selective kind would be desirable and necessary, especially that directed at pollution abatement of those industrial processes present in an equilibrium state.[51]

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[47] *Id.* at 158.
[48] *Id.* at 171.
[49] *Id.* at 24.
[50] *Id.* at 173-74.
[51] *Id.* at 174-75.

The degree of equality in material comfort or opportunity compatible with an equilibrium economy would not automatically be solved in the transition to this condition, but neither would it necessarily be aggravated. As is presently true, political decisions would have to be based on the difficult trade-offs associated with this problem. The authors of LIMITS strongly believe that it is a myth that continued patterns of present growth will lead humanity closer to some equality of welfare or opportunity.[52] They do recognize a trade-off which transition requires:

> Equilibrium would require trading certain human freedoms, such as producing unlimited numbers of children or consuming uncontrolled amounts of resources, for other freedoms, such as relief from pollution and crowding and the threat of collapse of the world system. It is possible that new freedoms might also arise—universal and unlimited education, leisure for creativity and inventiveness, and, most important of all, the freedom from hunger and poverty enjoyed by such a small fraction of the world's people today.[53]

The authors of LIMITS clearly considered the transition from uncontrolled growth to global equilibrium desirable, but they did not address the means of making the transition. They called for more information in order to manage the transition, as well as more participation in designing suitable policies. In accord with their training and bias, they called for such additional information and participation to occur within a "system structure" so that it could be explicitly understood and its consequences upon global conditions determined. However, they also stressed the need for a simultaneous start at solving problems while further information was gathered:

> . . . we end on a note of urgency. We hope that intensive study and debate will proceed simultaneously with an ongoing program of action. The details are not yet specified, but the general direction for action is obvious. Enough is known already to analyze many proposed policies in terms of their tendencies to promote or to regulate growth.[54]

Pursuant to this urgency, they strengthened their call for a conscious change of direction:

> Taking no action to solve these problems is equivalent to taking strong action. Every day of continued exponential growth brings the world system closer to the ultimate limits to that growth. A decision to do

[52] *Id.* at 174-80.
[53] *Id.* at 179-80.
[54] *Id.* at 182.

> nothing is a decision to increase the risk of collapse. We cannot say with certainty how much longer mankind can postpone initiating deliberate control of his growth before he will have lost the chance for control. We suspect on the basis of present knowledge of the physical constraints of the planet that the growth phase cannot continue for another one hundred years. Again, because of the delays in the system, if the global society waits until those constraints are unmistakably apparent, it will have waited to long.[55]

The reactions to LIMITS at the March 2, 1972, Smithsonian Symposium rested primarily upon intuition and professional prejudice. Politicians guardedly expressed concern over the dire predictions, while simultaneously staying away from any endorsement of action, except for further study and contemplation. Businessmen questioned the adequacy of evidence that growth must come to an end if world collapse is to be prevented. Environmentalists jumped at the chance to use the study as hard evidence for their long-standing contention that curbs must be placed upon man's activities so that a harmony with nature can be achieved. Economists dismissed the study as one more version of Malthusian analysis, which had been continually disproven by progress and growth. Journalists played each side off against the other, giving equal credence to each comment and being overwhelmed by the inconclusiveness of the debate.[56] Very few of these early reactions were based upon a careful reading of LIMITS. Rather, they depended upon the publicity released by Potomac Associates prior to the Smithsonian Symposium, the verbal presentation by Dennis Meadows, and the subsequent discussion at the Symposium itself.[57]

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[55] *Id.* at 183.

[56] Various reactions at the Symposium are reflected in Reinhold, *Warning on Growth Perils Is Examined at Symposium, supra* note 25; Lewis, *Ecology and Politics: I*, New York Times, March 4, 1972, at 27, col. 1; Baker, *The Machine, the Doom and the Fool*, NewYork Times, March 5, 1972, at IV, 13, col. 3; Lewis, *Ecology and Politics: II*, New York Times, March 6, 1972 at 33, col. 1; Hodson, *Growth and Survival*, New York Times, March 8, 1972 at 43, col. 2; *To Grow or Not to Grow*, NEWSWEEK, March 13, 1972, at 102-03; *Hard Sell, supra* note 20, at 1088-91; *On Reaching a State of Global Equilibrium*, New York Times, March 13, 1972 at 35, col. 2; *The Ultimate 'Silent Spring'?*, CHEMICAL WEEK, March 15, 1972, at 40; Kriss, *When Growth Becomes Cancerous*, SATURDAY REVIEW, March 18, 1972, at 22.

[57] For a sampling of reviews, *see World Model Forecasts Collapse*, CHEMICAL AND ENGINEERING NEWS, March 6, 1972, at 10; *Economic Growth Versus Human Survival*, 101 SCIENCE NEWS 165-66 (March 1972); *The MIT Report: Is Doomsday Really That Close?*, BUSINESS WEEK, March 11, 1972, at 97-98; a series of two articles by Silk, *Questions Must Be Raised About the Imminence of the Disaster*, New York Times, March 13, 1972, at 35, col. 2 and *On the Imminence of Disaster*, New York Times, March 14, 1972, at 43, col. 3, condensed and reprinted as Silk, *Questioning the Imminence of Disaster*, 140 CURRENT 3-8 (May 1972); Gilluly, *Limits to Growth: Debating the Future*, 101 SCIENCE NEWS 202-04 (March 1972);

III. Critical Responses To *World:2* and *World:3*

While reviews of Limits were diminishing in the popular press by mid-1972, a massive critical reaction to the global models used in World Dynamics and Limits was building in the scientific arena. Glimpses of this debate reached the public when certain fundamental weaknesses of these models were charged.[58] While the reports on this debate are voluminous,[59] the discussion itself can be categorized into a few fundamental areas of concern which consistently appear in the responses to the global models behind the *Predicament of Mankind*. The remarks which follow are not intended to be comprehensive, but rather are designed to convey some of the diversity of opinion concerning the entire modeling effort and its merits.

A. Criticism of the Model

The problems dealt with in Limits and World Dynamics demand long-term solutions, even though these solutions require rapid initiation if there is to be any hope of moderating adverse consequences. Some critics argue that the M.I.T. studies ignore short-term problems like famine, threat of nuclear war, and political unrest and that they wrongly divert public attention toward distant problems.[60] According to such criticism, what little effort and goodwill exists for solving world problems must be concentrated on immediate areas of concern and not diffused over complex and distant issues. These critics suggest that people may be left feeling helpless in the face of overwhelming "trends" emanating from "fatalistic doom-mongering."[61] Thus far, *no* significant efforts have been diverted toward studying, let alone designing, solutions to long-term prob-

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Edelson, *A Computer Views our Future with Alarm*, Book World, March 26, 1972, at 13; Hirst and Schuck, *The Limits to Growth: A Review*, 36 The Living Wilderness 38-39 (Spring 1972).

[58] For examples of the "exposure" of these weaknesses, *see Fall of Rome*, The Economist, June 3, 1972, at 78-81; *Homilies for the Club of Rome*, 238 Nature 237-38 (August 1972); *Limits to 'Limits'*, 102 Science News 153 (September 1972); *More Coals of Fire for Club of Rome*, 239 Nature 248-49 (September 1972); Streatfeild, *No Limit to the Growth Debate*, 73 New Scientist 531-33 (1973).

[59] Nordhaus, *World Dynamics:Measurement Without Data*, 331 Economic Journal 1156-83 (December 1973); Forrester, *The Debate on World Dynamics: A Response to Nordhaus* (December 1973), published in: 4 Policy Sciences (June 1974); Naughton, *A Little Global Difficulty*, 42 Encounter 72-77 (January 1974).

[60] Haq, *The Limits to Growth: A Critique*, 9 Finance and Development 8 (December 1972); Beckerman, *The Myth of Environmental Catastrophe*, 24 National Review 1315 (November 1972).

[61] Dator, *The Limits to the Limits to Growth*, World Future Society, May 10, 1972, at 10.

lems. This inaction may be for good reason, since people "discount" future possibilities very heavily in determining current behavior.[62] Further, the short-term problems are often simply manifestations of the longer-term directions toward which the basic variables of the Meadows study are headed. The problem remains, however, to introduce perspective toward the long-run into short-term efforts at alleviating world problems.

Population growth may be the root of the problem, according to the M.I.T. study. These models develop relationships between population growth and concomitant changes in food requirements, pollution, resource depletion, and capital requirements. Thus, explosive increases in population result in explosive pressures on the other variables in the world system.[63] The population level is also likely to overshoot the support levels of other necessary variables such as food, resulting in a built-in tendency for the system to crash. These premises are, of course, controversial.[64] First, some observers read the empirical evidence on demography differently than the Meadows group did. They argue that:

> . . . fertility has already started to decline in a number of countries. Of the sixty-six countries for which accurate data are available, as many as fifty-six show a decline. Most demographers are agreed by now that the 1970's will see the population growth rate reach a plateau so that by 1980 population growth rates will tend to decline, slowly at first and rapidly thereafter.[65]

Such an argument alone is insufficient to diffuse the global catastrophe predicted in LIMITS. Since even this "natural" reduction in growth rate will lead to much larger levels of population before the slowdown takes effect. But some population "optimists" foresee the possibility of going further in checking population growth, even at low income levels, by vigorous programs. Such a possibility is not built into the LIMITS model, which links fertility and mortality largely to economic factors so that only increasing per capita industrial production can provide the education and reinforcement necessary to reduce population.[66]

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[62] Linstone, *On Discounting The Future*, 4 TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE 335-38 (1973).

[63] For a counter argument concerning the link between population growth and pollution, *see* Fisher, *Population and Environmental Quality*, 19 PUBLIC POLICY 19-35 (Winter 1971).

[64] For an overview of the criticism of the population sector, *see* Page, *The Population Sub-System*, in DOOM, *supra* note 5, at 43-55; Page, *Population Forecasting*, in DOOM, *supra* note 5, at 159-74.

[65] Haq, *The Limits to Growth: A Critique*, *supra* note 60.

[66] *Id.*

Other critics turn the argument around and use "inevitable population growth" as an argument why growth cannot stop. Rather than attack population growth today and only see the results much later, they argue for increasing the resources to support these masses.[67] The prospect of this same "inevitable" population growth can also compel a different conclusion, namely that stabilization of the world system leading to global equilibrium must begin immediately. Further, the industrialized countries are presumed to be capable of reducing demand on world support levels so that population growth can be handled over an interim when its growth is somehow moderated.[68]

If population cannot long continue to grow at its current rate, a unique optimal long-term level remains unclear.[69] An optimal level requires trade-offs with levels of personal freedom, as well as material and social standards of living. These choices are clearly reflected in a description of the probable consequences of continued growth:

> Doom does not necessarily mean that man will soon cease to exist, but that he is perceptibly evolving toward the life style of the great majority of organisms on this planet—a life without variety or choice or beauty. This kind of doom may be much harder to avoid than extinction.[70]

What sense can be made out of the conflicting views on population? Was LIMITS too pessimistic about the urgency of the need to curtail birth rates or, alternatively, about the possibility that developing nations can internally spawn demographic transitions toward more stable populations? The former might be true if technology could be counted upon to provide food and relatively pollution-free products in quantities far beyond the most optimistic assumptions of the *World:3* study. The latter might be true if developing nations could follow the lead of industrial countries and decrease birth rates as economic prosperity increases. It remains, however, to be seen how these countries could break out of low-level traps where small increases in income are eaten by up growing populations. Regardless of the view held concerning the LIMITS study, population remains a crucial ingredient in any projection about the future. It is even more

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[67] Bruce-Briggs, *Against the Neo-Malthusians*, 58 COMMENTARY 29 (July 1974).

[68] Hapke, *The Limits to Growth: Implications for the United States*, 4 ZPG NATIONAL REPORTER 8-10 (May 1972).

[69] For a discussion of possible population models, *see* Population Reference Bureau, *Man's Population Predicament: Three Models of the Future*, 71 THE ENVIRONMENTAL JOURNAL 29-31 (October 1971).

[70] P.W. BARKLEY AND D.W. SECKLER, ECONOMIC GROWTH AND ENVIRONMENTAL DECAY 5 (1972).

crucial if it is viewed as the cause of pressure on other variables, as it was in the M.I.T. study.

Views concerning resource exhaustion separate the technological optimists from the pessimists.[71] The optimists wish to project the experience of the last century forward and assume that technology will allow exploitation of ever-poorer deposits of raw materials and will create a substitute for any material which is exhausted, thus leading to general abundance even if specific materials approach extinction.[72] If this technological adaptation process is able to occur, one of the restraints to continued growth, natural resource scarcity and eventual exhaustion, will have been removed.[73]

The pessimists, sometimes known as "Malthusians," view technology as a mixed blessing. Even if new sources of energy and raw materials could be developed, the attendant society costs must be considered.[74] Certainly there are social and environmental costs beyond the market prices (as currently measured) paid by consumers of this new technology.[75] Radiation hazards, heat dissipation, disruption of natural ecosystems, pollution of water and air, and many other spin-off effects of technology cause some critics to question whether the general welfare is actually increased by such technological discoveries, assuming that they are sustainable into the future.[76] Others accept the necessity of continued technological "fixes," but question their eventual effectiveness.[77]

The *World:2* and *World:3* models developed a single variable to

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[71] For a discussion of these "ideological poles" or extreme positions about the future of the world, *see* Boyd, *World Dynamics: A Note*, 177 SCIENCE 518 (August 11, 1972).

[72] Sharpe, *Limits to Growth - Review*, 9 SOCIETY 92 (September/October 1972); Patel, *The Club of Rome Report - A Dissenting View*, 1 ASPEN INSTITUTE QUARTERLY 5 (Fall 1972); Wiener, *The Future of Economic Activity*, 408 ANNALS OF THE AMERICAN ACADEMY 52 (July 1973).

[73] For a description of how the world models might work with more optimistic assumptions about technology and resources, *see* Page, *The Non-Renewable Resources Sub-System*, in DOOM, *supra* note 5, at 33-42.

[74] For a "pessimist's" view *see* E.J. Misham, TECHNOLOGY AND GROWTH: THE PRICE WE PAY (1969).

[75] For a discussion of how economists view the pricing mechanism and LIMITS, *see* Gordon, *Today's Apocalypses and Yesterday's*, 58 AMERICAN ECONOMIC REVIEW 106-10 (May 1973); Rosenberg, *Innovative Responses to Materials Shortages*, 58 AMERICAN ECONOMIC REVIEW 111-18 (May 1973); Bradley, *Increasing Scarcity: The Case of Energy Resources*, 58 AMERICAN ECONOMIC REVIEW 119-25 (May 1973).

[76] Critical or guarded views of technology's future role are found in Schatz, *Grim Model*, 24 AMERICAS 58-59 (May 1972), Holley and Seifert, *Further Comments: Limits to Growth*, 64 TECHNOLOGY REVIEW 68-69 (July/August 1972); Forrester, *The Fledgling Cheermonger*, 73 CAMBRIDGE REVIEW 70-73 (February 1973).

[77] Weinberg, *Prudence and Technology: A Technologist's Response to Predictions of Catastrophe*, 21 BIOSCIENCE 338 (April 1, 1972).

represent worldwide pollution and then used it in determining how other variables would relate to it. But, of course, pollution is far more complex and diverse than its representation in these models. Is this gross aggregation useful in representing possible future conditions? One analysis of the pollution sector concludes: "The World 3 sub-system advances neither our understanding of pollution, nor of its interaction with other aspects of world behaviour."[78] One reason for this rejection was the predicted oversight of local and regional pollution problems, which would probably generate further concern and social response. But, "by aggregating all pollutants, and assuming that they behave in some composite way, attention is drawn away from what are urgent, and still soluble problems, and diverted into speculation upon an imaginary race against time between Life and Global asphyxiation."[79]

A concomitant assumption of the LIMITS model was that the most optimistic reduction of pollution possible would be to a level one-fourth that which existed in 1970. Critics have questioned the presumed impossibility of greater reductions in this world-wide level.[80] These critics assume that pollution will become so concentrated at local levels that social-political reactions will occur which, in turn, will call forth appropriate technological mechanisms to produce environmental improvement or avoid continued degradation. One key element in this assumption is that economic growth probably will generate the social-political pressures for correction via a growing demand for the amenity of a more livable environment.

Human response to changing conditions is viewed by many as the most important missing element in the LIMITS model. Man's learning capacity and adaptability are viewed as extraordinary, and thus the model's predicted overshooting of limits and world collapse is suspect. The argument hinges on the "unpredictability" of man:

> For it is in the realm of human actions that major discontinuities have occurred in the past and may occur again, while man's history provides not one single example for a sudden discontinuity in physical attributes of the world. It is in the nature of purposeful adaptation that the course of events can be changed dramatically if social constraints are experienced as intolerable, if aspirations remain unfulfilled and if confidence in the ruling political powers disintegrates. It makes no sense in this context to talk of exponential growth in a finite world. Man's inventive-

[78] Marstrand and Sinclair, *The Pollution Sub-System*, in DOOM, *supra* note 5, at 88.
[79] *Id.*
[80] Singer, *Do We Dare To Grow?*, 215 THE NATION 527-31 (November 1972).

> ness in changing social arrangements is without limits, even if not without hazards.[81]

This line of reasoning does not envision growth rates continuing indefinitely, but considers physical limits misleading, since an adaptation process could ease society into new equilibria.

It is certainly true that no social adaptation process was built into LIMITS. A set of "optimistic" assumptions was made, however, concerning how far this adaptation could conceivably go in modifying the behavior of the variables. This refusal of the authors of LIMITS to rely heavily on social adaptation stems perhaps from the *system dynamics* belief that social systems are *counter-intuitive* and that some decisions must be made about the future of the world before the end result of status quo policies becomes widely evident. The critics have not clarified their basis for ignoring the recognition lag which LIMITS assumed societies experience concerning problems whose impact will be felt only after it may be too late to take corrective action to forestall the eventual disaster.

B. Global Equilibrium

The necessity of stabilizing levels of population and material output, in balance with the finiteness of resources and the environment, is the policy prescription of LIMITS. This prescription has generated perhaps even greater controversy than have the weaknesses of the specific model used to conclude that such an equilibrium offered the only feasible means of perpetuating global human prosperity. Many of the criticisms aimed at specific aspects of the model reach the implicit or explicit conclusion that any substantiated weakness of the *World:3* model invalidates its predictons that global equilibrium will be essential. In addition, there has been strong sentiment that such a prescription spells another kind of doom for large segments of the globe:

> Perhaps the most devastating criticism of the Club of Rome stop-the-growth thesis comes from those who argue that it is a middle-class movement that goes directly against the interests of the poor—to say nothing of the billions of people who barely stay alive in the underdeveloped parts of the world. The problem of the poor nations is not pollution. Their problem is hunger and deprivation.[82]

Thus, many observers are as repulsed by the suggested remedy in

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[81] Jahoda, *Postscript on Social Change*, in DOOM, *supra* note 5, at 215.

[82] *Growth or No Growth?*, FORBES, May 15, 1975, at 100.

LIMITS as by its predictions of eventual catastrophe: "This status quo prescription—the report calls it 'global equilibrium' —is as chilling as the doomsday prophecy."[83] Of course, the unpleasantness of global equilibrium is not sufficient to eliminate its necessity. Attacks on LIMITS' structure and assumptions provide a more constructive way to "prove" the invalidity of its policy prescriptions.

An associated controversy centers around the consequences of such a global equilibrium, assuming that it becomes necessary. What distribution of product would exist? Could economies stabilize at such levels and remain there indefinitely?[84] Will it also result necessarily in an ecological balance, such that pollution does not increase? Such questions reflect the deep concern and distrust that people have of a no-growth world. The majority views growth of product and technology as a means of reducing income inequalities and promoting the general welfare, while no-growth is assumed to do just the opposite. It will take considerably more than LIMITS to convince peoples and nations that continued economic growth is neither beneficial nor possible. Most ask why it is not possible, as a limiting case, to have continued economic growth without associated pollution and population growth.

C. Absence of Solutions

The work of Forrester and Meadows has been termed irresponsible doomsday mongering because it fails to suggest the means by which solutions can be found to the problems it raises. Critics argue that while the studies call for radical changes in worldwide behavior, they hardly specify how painful this transition will be and for whom. Furthermore, the studies ignore the basic question of mobilizing a world effort.[85] Related criticism involves the potentially destructive nature of the dire predictions themselves. Even if the predictions are accurate, they may bring forth unintended responses. People may feel helpless to avert such consequences and lapse into

[83] *Can the World Survive Economic Growth?*, TIME, August 14, 1972, at 56.

[84] The consequences of no-growth economics are only now beginning to be explored. *See* TOWARD A STEADY-STATE ECONOMY (H.E. Daly ed. 1973); M. Olson and H. Landsberg (eds.) *The No-Growth Society*, 102 DAEDALUS 1-245 (Fall 1973); ECONOMIC GROWTH VS. THE ENVIRONMENT (W.A. Johnson & J. Hardesty eds. 1971); THE ECONOMIC GROWTH CONTROVERSY (A. Weintraub, *et al.* eds. 1973).

[85] Even observers who accept the basic conclusion that collapse is feasible object to the lack of specific solutions offered. *See* Heilbroner, *Growth and Survival, supra* note 59. For suggested scenarios different from those of Forrester and Meadows, *see* Gabbor, *The New Responsibilities of Science*, 72 SCIENCE POLICY 1-8 (May/June 1972); Gladwyn, *The Logic of Growth*, 3 ECOLOGIST 130-33 (1973).

anxiety, depression, and social as well as political radicalism.[86] Another result may be a growing split between have and have-not nations, with confrontation accentuated.[87] Neither of these complaints involves the validity of the predictions; rather they ask what will be the likely consequence if such predictions are widely believed. Perhaps they highlight some of the consequences of the widespread debate over the issues raised in LIMITS.

IV. LASTING CONTRIBUTIONS OF THE M.I.T. WORK ON GLOBAL MODELS

Many of the above criticisms concerning *World:2* and *World:3* as models of the world's predicament do identify actual weaknesses. However, a number of valuable results have flowed from the Club of Rome's support for these global studies and the ensuing controversy. The time which has elapsed since the debut of LIMITS has been sufficient to separate the strengths and weaknesses of this particular global modeling effort and to indicate its overall contribution.

A. Weaknesses

The behavior of any world model built by the use of *systems dynamics* is highly dependent upon the assumptions and data used, with social phenomena being extremely difficult to handle. Some critics charge that the model designed in LIMITS was useless: "If the work is intended to be a serious statement about the structure of the global economy and society and to inform debate over the policy issues stemming from growth, it is a fraud."[88] Other, more charitable, observers charge that LIMITS relied too heavily on *a priori* formulations of relationships between variables, and thus was simply a means of articulating the intuitive values and subjective preferences of the model builders.[89] Further, manipulation of such a "subjective" model could result in any conclusions desired by the authors. Critics view with disapproval what they consider to be a failure adequately to incorporate available knowledge as data and assumptions.[90] If "equally plausible" assumptions are substituted

[86] DeNike, *The Dangers of Dire Predictions*, 72 THE FUTURIST 118-20 (June 1972).

[87] Dickson, *The Limits to Growth and World Development*, 72 NEW SCIENTIST 306-07 (May 1972).

[88] Koehler, *Limits to Growth - Review*, 35 JOURNAL OF POLITICS 513 (May 1973).

[89] For an example of this argument, *see* Bray, *Growing Strong*, 14 ENVIRONMENT 43-45 (May 1972).

[90] This weakness made the model suspect in many persons' eyes, including the World Bank.

for some of those used in the LIMITS model, considerably different conclusions are reached by some critics who likewise find the model to be very sensitive to these changes in inputs.[91]

Some claim that *system dynamics* is utterly simplistic and tends to reinvent economics, demography, and many other disciplines in the form of a few equations.[92] Given this simplicity, the resulting global models are deemed insufficient to provide policy guidelines, although they can be useful as first steps in understanding the complex interactions of the global system.[93]

One of the most obvious weaknesses of LIMITS TO GROWTH has been the lack of public documentation for the *World: 3* model underlying the book. When LIMITS was first released to the public in March, 1972, the detailed model structure was lacking. The model was inappropriate at that point for inclusion in a book aimed at the general public. Promises were made then regarding quick release of the technical documentation so that the scientific community could replicate and verify the study's results. Inordinate delays occurred in making the documentation finally available to the public.[94] There has still not been any public explanation for this unfortunate delay, leaving the authors open to the charge that they attempted to head off the arguments of critics by revising the basic model prior to release. However, there had been limited distribution of the underlying technical model in a preliminary version to various researchers.

Another weakness was the over-emphasis on the model's present usefulness as input to policy decisions. In light of the grossly aggregated structure and hasty construction, only *system dynamics* advocates were willing to place unrestrained confidence in the model and its suggested alternatives to global catastrophe. Other sympathetic observers could agree with the *need* for such a model, but found themselves stymied by the controversy regarding specific weaknesses in the model which might invalidate the policies suggested to achieve global equilibrium. While it is impossible to refute the

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See, More Coals of Fire For Club of Rome, supra note 58.

[91] A sample of this type of critical analysis was widely reported as a "flaw" in the M.I.T. models. *See* Oerlemans, Tellings, and DeVries, *World Dynamics: Social Feedback May Give Hope for the Future*, 238 NATURE 251-55 (August 1972); *Homilies for the Club of Rome, supra* note 58; *Limits to 'Limits', supra* note 58; St. John, *Fear and Fantasy in Future Folly*, New York Times, December 5, 1972 at 43, col. 3.

[92] Kaysen, *The Computer That Printed Out WOLF, supra* note 59.

[93] For example, *see* Foy, *Painting the World With a Wide Brush*, 72 NEW SCIENTIST 261-63 (May 1972); Bray, *A Model of Doom*, 238 NATURE 112 (July 1972).

[94] DYNAMICS OF GROWTH IN A FINITE WORLD, *supra* note 31.

urgency the authors felt for these problems, many critics found their suggested solutions unpalatable and not substantiated by irrefutable models.

Another problem involved the paucity of empirical support for many of the relationships posited in the models. In some cases, both supportive and contradictory information existed for the relationships built into the models. That this data was not fully incorporated into the underlying studies opened the entire exercise to charges of subjective reconstruction of existing knowledge. Certainly there is room for the authors to reject this charge and to claim that they reviewed the essential information. However, traditional disciplines were able to criticize the use of data by the authors of LIMITS even more readily because of the rush to communicate the model in a popular manner and to "spread the word" about problems judged critical and imminent by the authors and supporters prior to completion of the model.

A final, related weakness was the relative lack of new material in LIMITS such as would justify its urgent publication prior to ironing out some of the problems mentioned above. WORLD DYNAMICS and LIMITS are essentially the same world model, the difference in the public's eye being the sensationalism of the latter. Many critics were disappointed that LIMITS did not delve more deeply into the relationships first posited in WORLD DYNAMICS. It is really the technical report THE DYNAMICS OF GROWTH IN A FINITE WORLD which is a sequel to WORLD DYNAMICS because it matches the *World:2* report in providing technical information on *World:3*. LIMITS, then, was left open to the charge that the authors and supporters wanted the publicity generated by it, but were unwilling simultaneously to subject themselves to the scientific criticism which could only be generated from analysis of the underlying technical structure of the *World:3* model.

B. Strengths

There are certainly strengths to counterbalance these weaknesses. First of all, the world needed a jolt to its complacent attitude about world problems and particularly to its apathy concerning the future of man on this globe. The Club of Rome's support for the *World:2* and *World:3* models and the related publicity was timely in awakening public opinion and controversy on these important issues. Perhaps the less than strictly professional or scientific method used to

[95] DOOM, *supra* note 5.

present the results of these models and their "message" was worth the price paid in terms of the researchers' and supporters' impugned respectability by the established scientific community.

Few would dispute that these models were fresh analyses of presumably interconnected problems. The *system dynamics* approach did sweep aside the assumed hinderance of traditionally "narrow" disciplines. It is unfortunate that so much of this response was emotional and even hysterical, instead of reasoned and constructive. There were weaknesses which critics could have exposed calmly. While the public controversy, and even sensationalism, has seemed unprofessional to many in the scientific community, it has been healthy in prompting a more concerted response by the critics than might otherwise have occurred. The problems involved are too important to remain exclusively within academic circles. There is a compelling need for scientists to re-examine their assumptions and work toward broad explanations of long-term global growth and progress.

V. Beyond Limits: Mankind at the Turning Point and Other Modeling Efforts

This model-building activity has provided impetus for additional research on global problems. Perhaps the controversy has been worthwhile because the refinement of global model building has been accelerated far beyond the level which would have been achieved without this push. Regardless of the weaknesses of these initial models, they have crystallized attention around verifying or countering their conclusions. This crystallization fulfills one of the hopes of the Limits authors and supporters that more concern and attention would be directed toward conditions which might have critical and sometimes irreversible global consequences.

The debate prompted by Limits is perhaps best reflected by Models of Doom, the first reasoned critique by persons who had access to the underlying technical model. This response has been strengthened by the subsequent rebuttal by the Limits authors. Interchanges of this nature come closest to the open, scholarly debate expected by the scientific community.[96] Another response has emerged in the form of stimuli provided to other research on growth and its consequences. This work often attacks one sub-sector of global models and attempts to improve the knowledge of relationships and possible future outcomes. Such inquiry has probably been

[96] Meadows, *et al.*, *A Response to Sussex*, 217-40 in Doom, *supra* note 5.

given a boost by the controversy over the LIMITS models, as well as by a series of ensuing world events which have underscored the urgency and critical nature of this debate.[97]

The Club of Rome has remained active in supporting further research and in pressing for policy changes in light of their studies and conclusions to date. Their first general meeting after LIMITS was released, occurring in Paris during January, 1973, provided the Club with a chance to reassess its goals and the reactions to its involvement in supporting the LIMITS studies. To a great extent the Club had become too exclusively identified with the notion of zero growth and its connotations. Even prior to this Paris meeting, however, additional projects were receiving support. These projects entailed expanded and disaggregated research on the "predicament of mankind" and methods of assessing its future condition.[98] Another general meeting was held in Tokyo during October, 1973, to review the results of twenty different research efforts, some supported by the Club indirectly. The Tokyo meeting also provided an opportunity to reaffirm their concern about the study of and solutions to this growing list of global problems:

> (1) the abolition of war and violence, (2) the reassessment of economic growth objectives, (3) the conservation of the world's unrenewable resources, (4) harmonious socio-economic development, (5) stress on the quality of life, (6) more equitable distribution of wealth, (7) the orientation and management of technology, (8) population policies, (9) the need for the participation of individuals in decision-making and (10) the development of human potential.[99]

In pursuing these visionary goals, the Club continued to push for policy redirection. A meeting of "minor" heads of state sponsored

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[97] Efforts to catalog this growing research effort have been spearheaded by the Woodrow Wilson International Center For Scholars at the Smithsonian Institution. RESEARCH ON GROWTH: AN INVENTORY OF EFFORTS IN THE UNITED STATES AND ELSEWHERE, Woodrow Wilson International Center For Scholars - Smithsonian Institution (Preliminary Edition, March 1974). *See also* WORLD MODELS: AN INTRODUCTION TO THE STATE OF THE ART, Futures Lab (August 1975).

[98] A statement by the Club outlines activities and policy stands as the result of the Paris Meeting. Club of Rome, *The Club of Rome Answers Its Critics—And Pushes On*, 12 WAR/PEACE REPORT 21-29 (May/June 1973). *See also* Peccei, *The Limits to Growth: Interview with the President of the Club of Rome, Aurelio Peccei*, 26 UNESCO COURIER 11-12 (January 1973); Peccei, *Shoulder to Shoulder to Shoulder to Shoul*, New York Times, February 4, 1973 at 35, col. 2; *The Club of Rome—The New Threshold*, 5 TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE 335-48 (1973).

[99] Tokyo Conference of the Club of Rome, 21 JAPAN QUARTERLY 10-14 (January/March 1974).

by the Club was held in Salzburg during February, 1974.[100]

Several Club of Rome "second generation" studies will serve as examples of the mushrooming field of global modeling efforts.[101] Dennis Gabor and a group of technological optimists, with support from the Club and the Canadian government, have set out to explore the potential of science and technology in pushing back the limits forecast by the M.I.T. models, especially those in the sectors of non-renewable materials, food, and energy.[102] While the report is still in the preparation stage, their findings indicate that political and social limits will become problems long before actual physical limits could be reached. This discussion shifts the emphasis to managerial and behavioral attributes as critical factors in the world's future, a point perhaps underemphasized in the LIMITS studies.

Developing countries have long resented the nature and findings of the LIMITS models because of their implications for the poorer nations. Since this resentment has been especially strong in Latin America, a group at the Institute Bariloche in Argentina has set out to look at world futures from the viewpoint of the Third World, a viewpoint which encompasses a set of assumptions different from that of the LIMITS authors.[103] This examination is intended to utilize an egalitarian model concerned with the prerequisites of food, shelter, education, and the other elements necessary to provide a decent level of welfare for the world's masses. These needs take account of varying population growth rates and welfare requirements on a regional basis. While very theoretical in nature, the study makes a series of assumptions about relations between developing and developed regions and explores the length of time remaining for the Third World to continue growth and still provide minimum welfare prerequisites.

A third study views continued population growth as inevitable and explores the demands on world infrastructure to handle a doubling of population in the next thirty-three years. A group of economists at the University of Amsterdam is involved in determining whether the prerequisites for this population can be provided

[100] *'Medium' Nations Find a Forum in Salzburg*, New York Times, February 10, 1974 at 22, col. 5.

[101] For a description of these studies, *see Alexander King on The Club of Rome Today*, 4 SIMULATION IN THE SERVICE OF SOCIETY 1-4 (August 1974). A completely different type of world model is represented by the first three studies in the Institute for World Order's "world order models project." ON THE CREATION OF A JUST WORLD ORDER (S.H. Mendlovitz ed. 1975); R. LOTHARI, FOOTSTEPS INTO THE FUTURE (1975); R.A. FALK, A STUDY OF FUTURE WORLDS (1975).

[102] *Alexander King on the Club of Rome Today, supra* note 101.

[103] *Id.*

and what the impact of population doubling will be from the standpoint of economics as well as from that of human suffering.[104]

One of the studies supported by the Club of Rome and authored by two of its members became the "Second Report to the Club of Rome." It was presented at a general meeting in Berlin during October, 1974. This second report was termed a "Son of LIMITS"[105] because it deals with global variables through a computer model of possible future conditions. The authors coordinated their research for this report, MANKIND AT THE TURNING POINT (TURNING POINT),[106] from Case Western Reserve University and Hanover Technical University. Unlike LIMITS, this work reflects a disaggregation of the world into ten sub-regions[107] and introduces policy strategies into the model as ways to ameliorate world and regional problems. Thus, the model offers a *gaming* technique for policy makers to test their strategies toward problems. The concept of "organic growth" is posited as a replacement for uncontrolled and undifferentiated growth. This is likened to healthy biological growth which takes place only within the bounds of a total system and becomes a functionally differentiated part of that system. The contrasting undifferentiated growth is compared to cancerous biological growth which eventually kills the system itself.[108] The tone of TURNING POINT is in stark contrast to LIMITS. This new study is billed as a "decision-aiding" tool to test alternative plans for "anticipatory action" on a national, regional, and global basis. It diffuses the growth controversy by calling for selective growth to balance regional groupings of nations. However, its underlying philosophical bent and feeling of urgency concerning world problems continues in the manner of previous Club of Rome efforts:

> Mankind cannot afford to wait for change to occur spontaneously and fortuitously. Rather, man must initiate on his own changes of necessary but tolerable magnitude in time to avert intolerably massive and externally generated change. A strategy for such change can be evolved only in the spirit of truly global cooperation, shaped in free partnership by the world's diverse regional communities and guided by a regional master plan for long-term organic growth. All our computer simulations have shown quite clearly that this is the only sensible and feasible

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[104] *Id.*

[105] *The Club of Rome: Act Two*, TIME, October 21, 1974, at 108-09.

[106] M. MESAROVIC & E. PESTEL, MANKIND AT THE TURNING POINT (1974) [hereinafter cited as TURNING POINT].

[107] *Id.* at 32-55.

[108] *Id.* at 1-9.

> approach to avoid major regional and ultimately global catastrophe, and that the time that can be wasted before developing such a global world system is running out. *Clearly the only alternatives are division and conflict, hate, and destruction*[109] [emphasis in original].

TURNING POINT has been largely ignored, much as WORLD DYNAMICS had been previously.[110] The authors and the Club intentionally avoided generating a controversy of the kind surrounding LIMITS. Also the tone of the report was designed to be optimistic. Decision-makers not only had the power to influence the course of future events, but this computer model was designed to give them insight into the likely consequences of policy options. Regional disaggregation meant that growth, while still limited globally, could occur in some regions if counterbalanced by no-growth in other regions. This approach appealed to the regions apparently destined by LIMITS' studies to perpetual poverty.[111] Of course, the consequences on those regions required to limit their growth are equally disturbing, but somehow seem more distant since such adjustments do not condemn millions to death or continued malnutrition.

Regional disaggregation in global models was undoubtedly essential. Policy options which could be implemented failed to emerge from the LIMITS models because of the gross aggregation involved in dealing with the world level of variables and relationships. The ten regions in TURNING POINT take on sufficiently homogeneous attributes to allow policies to be formulated and perhaps implemented.[112] Moreover, the relations between regions highlighted by the model are useful in demonstrating how alternative growth paths will impact various nations and regions. Such regionalization leads to a second contribution, the concept of organic growth. Growth will certainly continue to take place in some parts of the system. How such growth will be distributed and what will be the resulting consequences becomes the important question. In theory the idea of man-computer interaction as a *gaming* approach to policy formulation is

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[109] *Id.* at 157.

[110] Representative samples of the reviews are Boulding, *Conditional Optimism about the World Situation*, 187 SCIENCE 1188-89 (March 1975); Douglas, *Alternatives to Doomsday*, 106 SCIENCE NEWS 169 (October 1974); *Model Makers Keep Trying To See the Future*, BUSINESS WEEK, November 23, 1974, at 111-13.

[111] Douglas, *Alternatives to Doomsday, supra* note 110.

[112] The regions are North America, Western Europe, Japan, the rest of the Developed Market Economies, Eastern Europe, Latin America, North Africa and the Middle East, Main Africa, South and Southeast Asia, and Centrally Planned Asia. For a list of countries included in these regions, *see* TURNING POINT, *supra* note 106, at 161-64.

also desirable. Unless policy makers can benefit from computer models in some manner, they are unlikely to support quantitative approaches to world problems.

Several of the problems which plagued LIMITS are equally present in TURNING POINT. The computer model used is machine-specific, making it extremely difficult for others to duplicate the model and replicate its finding at present. LIMITS was written in a simulation language which is readily accessible and transferable to other computers. Unless the model behind TURNING POINT is handled likewise, very little dialog will be possible over this world model. The modeling effort in TURNING POINT is even more heroic than that undertaken in LIMITS due to the added complexity resulting from regional disaggregation of data and assumptions. As was the case in LIMITS, the charge can be leveled here that the richness of discipline-oriented approaches to these problems could not possibly have been fully inculcated into the model. Of course, the structure of the regional model can accept changes in data and relations as they become available to the modelers, but doubts about the validity of the conclusions reached in TURNING POINT are possible as they were for LIMITS (such doubts are probably possible for any large-scale model). Finally, this "second generation" world model leaves the reader dissatisfied with the degree of guidance provided concerning how to implement the necessary policy options needed to achieve the scenarios desired by the modelers. Once again the ability to translate desired future conditions into present steps of action is absent. While it is understandable that such impetus for policy changes is difficult if not impossible to describe, models lacking such guidance may be frustrating and unfulfilling exercises. Sooner or later there must be a translation of such global knowledge into guidance for implementable action. The TURNING POINT model attempts to demonstrate that only those scenarios leading to organic growth are sustainable and, therefore, that individual nations and regions should redefine their self-interest in light of such knowledge. Whether such advice will be heeded and what incentives will be necessary for policy makers to adopt such policies remain unanswered questions.

CONCLUSIONS

LIMITS has now been surpassed by other reports to the Club of Rome, and its errors and weaknesses have been exposed. Its lasting contribution lies more in the questions which it asked than in the answers which it provided, more in focusing public attention on

crucial issues of global futures than in specific descriptions of these possible futures. The issues raised by LIMITS transcend the crises of the moment but portend the future predicament of mankind. They are too important to be left solely to the "experts."

Global modeling has become a battleground of ideologies as competing groups strive to prove each other wrong or to surpass previous efforts. Their work will necessarily be technical, but the results must be debated by a broad spectrum of participants. Like the computers used to run them, global models have vast potential both to benefit and to harm mankind. The challenge is to channel this potential toward constructive ends and to provide a forum wherein conflicts and controversy can be rationally settled and not allowed to destroy the modeling activities and their potential benefits.