A SURVEY OF LIMITS TO GROWTH: IS MANKIND REALLY AT THE TURNING POINT?

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In his second message to Congress, Abraham Lincoln is said to have urged upon his young nation the necessity of boldly striking out on new paths in order to tackle the problems of the day:

> The dogmas of the quiet past are inadequate to the stormy present, [Lincoln reportedly said.] The occasion is piled high with difficulty, and we must rise with the occasion. As our case is new, so we must think anew and act anew. [1]

It is widely believed that Lincoln's message is apposite to the challenges faced by the world in the mid-1970s. Confronted as we are in the opinion of many observers with problems which are global in scope, the solutions that we seek must necessarily, it seems, be worldwide in scope. The challenges, furthermore, are seen as demanding urgent attention and action, and anything less could lead, it is surmised, to a catastrophe of global dimensions.

Much of the recent debate on the state of the world has centered on a 1972 study sponsored by the Club of Rome and published under the arresting title *The Limits to Growth*.[2] The study, a pilot for the Club's "Project on the Predicament of Mankind," set out to examine "the five basic factors that determine, and therefore, ultimately limit, growth on this planet — population, agricultural production, natural resources, industrial production and pollution."[3] The world view of the pilot project was later rejected by a second report to the Club, *Mankind at the Turning Point*, which adopted an organic regional approach.[4] The debate which had withdrawn from the glare of public

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1. Quoted in James Boyd, "Materials Supply: The Impact of Human Institutions," 191 Science (20 Feb. 1976), 650 at 653. This issue of Science was devoted exclusively to problems relating to materials and resources.

2. D.H. Meadows, D.L. Meadows, J. Randers and W.W. Behrens III, The Limits to Growth, (Washington D.C.: Potomac Associates, 1972).

3. Ibid., at x-xi.

4. Mihajlo Mesarovic and Eduard Pestel, Mankind at the Turning Point, (New York: E.P. Dutton

scrutiny to the seclusion of conference rooms and academic institutions, now has been brought to the notice of the public again with the Club's Philadelphia conference of mid-April 1976. But the proclaimed evolution in the Club's thinking, initially seen in *Mankind*, has not been disseminated widely.[5] In this paper, we shall restrict our vision to *Limits* and *Mankind*, and examine some of their features and shortcomings with due apologies to the respective authors for the distortions that may inadvertently have entered into a severe condensation of complex studies. We shall then review some aspects of the question of resources around which much of the debate seems to revolve. Finally, we shall deduce some tentative implications for the developing countries.

Some Fundamental Concepts

If any concept can be singled out as underlying the two studies, it is that of exponential growth or "undifferentiated growth," as it is called in *Mankind*.[6] "Nearly all of mankind's activities . . . can be represented by exponential growth curves," according to *Limits*.[7]

In actual practice, however, growth has often been more explosive than just exponential. The world's population, for instance, has increased in a super-exponential or faster-than-exponential fashion over the past three centuries.[8] That is, not only has the population been growing exponentially, but the rate of growth of the population has also been increasing. The consequences of such growth for one nation have been summarized as follows: "To cope with the population increase, India needs to build 1000 new schoolrooms every day from now on for the next twenty years, 1000 new hospital wards every day from now on for the next twenty years and 10,000 houses every day from now on for the next twenty years."[9]

& Co., Inc./Reader's Digest Press, 1974). The second report is seen as complementing and extending the underlying concepts of the first despite some conflicts between the two. See the Club's position on this, ibid., at 202-205.

5. "Scholars Favor Global Growth," The New York Times (13 Ap. 1976), p. 1 col. 5 continued p. 46 col. 1. The article implies that the Club of Rome has "shift(ed) its public image," to the extent that it "looks like a turnabout," a claim expressly made in a succeeding article, "Changing Limits to Horizons," The New York Times (14 Apr. 1976), p. 55 col. 2 continued p. 59 col. 1. Any change that may have occurred in the Club's thinking occurred with the publication of Mankind in 1974. The Times thus seems to have been behind the times by at least two years in this case. Further, neither a reading of Mankind nor that of the Times articles indicated to the author that the revised position on "organic growth" is a "turnabout" from Limits.

6. Mesarovic and Pestel, n.4 at 1-9, especially 3-4.

7. Meadows et al., 2 at 33.

8. Ibid., at 41-45.

9. Tarzie Vittachi, Executive Secretary of World Population Year for the United Nations, quoted in Mesarovic and Pestel, n.4 at 80. For comparison, it can be mentioned that during the four-

On looking at the second variable studied in *Limits*, industrial output, one finds that its growth rate has been even faster than the super-exponential increase in population.[10] At first sight this may seem to be desirable, bringing as it does an increase in the average consumption of goods and services for the world's people. Unfortunately, the picture is marred by the remarkably lopsided distribution of the world's output. And that is not the only drawback. For unchecked industrial and agricultural production also depletes nonrenewable resources and pollutes the environment with unsettling effects for the ecological balance. *Limits* finds that for 19 vital minerals and fuel resources — aluminum, chromium, coal, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, natural gas, nickel, petroleum, the platinum group, silver, tin, tungsten and zinc — the world usage rate is growing exponentially, and that for many of these, "the usage rate is growing even faster than the population."[11] To alleviate the consequences of a serious depletion of vital minerals, *Mankind* suggests that the "industrialized regions [of the world] put a stop to further overdevelopment by accepting limits on per-capita use of finite resources."[12] While one may applaud the intent of the proposal to place the burden of the curtailment on regions of excessive consumption, one is also forced to admit that the solution is as simple as it is politically unrealistic, and in this latter sense is hardly a solution that merits serious consideration.

It could perhaps be argued that estimates of resource depletion are based on known reserves and do not take into account future discoveries and developments in refining and processing technologies that could increase the availability of depletable resources. The sad truth, however, seems to be that no foreseeable increase in the resource base of the world can ward off the virtual exhaustion of nonrenewable resources for long.[13] It is known, for instance, that global reserves of

year period 1965-66 through 1968-69, 21,479 new schools were built in India and that the government estimated the overall housing shortage was increasing by more than 2 million units a year. India 1971-72, (Publications Division, Ministry of Information and Broadcasting, Government of India), at 64 and 479 respectively. The figures for schools have been computed from Table 26 on p. 64.

10. Meadows et al., n.2 at 45.

11. Ibid., at 69; 64-68. But see Earl Cook, "Limits to Exploitation of Natural Resources," 191 Science, 677, Table 2 at 679, where it is shown that the ratio of reserves to production for some minerals has been increasing between the years 1934 and 1974, indicating that new reserves have been discovered faster than they have been exploited and depleted. There must be a limit to this process, however, as has been found to be the case with mercury, which is an "essentially exhausted resource within the United States," ibid., at 681, and as is acknowledged to be the case with copper, ibid., at 679-80.

12. Mesarovic and Pestel, n.4 at 69.

13. "Exhaustion" in this connection is taken as being the limit of economic exploitability.

aluminum will last about 100 years at current consumption rates but just 31 years if the consumption rate continues to increase at its 1970 pace. Increasing the available aluminum reserves to five times the existing quantity extends the metal's availability from 31 to 55 years; that is, a four-fold increase in reserves extends the availability of the metal just 24 years under the assumption that consumption continues to increase at the 1970 rate.[14]

This underscores a second fundamental concept of the two reports prepared for the Club of Rome: The earth, for all its vastness and hitherto untapped resources, is essentially finite, thus placing an upper limit on all its resources. This concept affects the fifth variable studied in *Limits*, pollution. While polluting activities have been a part of the human scene at least since the Industrial Revolution — some prefer to take the argument back to prehistoric times — concern regarding the effects of pollutants on the natural environment — the ecosphere — is a recent development. Thus, despite the increased interest in, and attention being paid to, the environment today, knowledge in this area is still quite sketchy.[15] According to *Limits*, however, it is known that "the few kinds of pollution that have been measured over time seem to be increasing exponentially,"[16] and that most of these exhibit super-exponential characteristics, "growing faster than the population."[17] How long can such abuse of the ecosphere continue before the ecosystem undergoes change sufficient to alter appreciably the conditions of survival in significant portions of the globe? The answer depends on the absorptive capacity of the ecosystem, a subject as yet little understood. Meanwhile the polluting activities carry on as if there were no limits to the system's absorptive capacity.

Pollution also illustrates the natural delays that characterize ecological processes — delays between the time a pollutant is released into the environment and the time it has a measurable impact on human life. These delays not only mean that there will be similar delays between the time that controls are instituted and the time that the harmful effects decrease, but that we can expect the problems to get substantially worse for quite some time after pollution controls are set up.[18] The upshot is that controls must be set up long before the

14. Meadows et al., n.2 at 64, 71. The reserve quantity of aluminum is for bauxite expressed in aluminum equivalent. The reserve and consumption figures used in Limits are taken from Mineral Facts and Problems, 1970, US Bureau of Mines, (Washington D.C.: Government Printing Office, 1970).

15. Most of the 109 recommendations of the 1972 Stockholm environment conference, for instance, are directed toward research, collection and dissemination of data on the environment and the effects of pollution. See UN Doc. A/Conf. 48/14/Rev.1

16. Meadows et al., n.2 at 78, 81.

17. Ibid., at 81-84.

18. Ibid., at 89-92.

problem becomes a crisis — a requirement that goes against the grain of most present bureaucracies, which tend to put off problems until they can be treated as crises. According to one source, observers "are concluding on the basis of mounting and reasonably objective evidence that the length of life of the biosphere as an inhabitable region for organisms is to be measured in decades rather than in hundreds of millions of years."[19]

Having glanced at the parameters of the "world problematique," as the Club of Rome calls it, it may be expedient to treat *Limits* and *Mankind* separately from here on as they take different approaches to examine the predicament of mankind.[20]

Limits attempts to weave the five variables it studies — population, food, industrial output, resources and pollution — into a "world model." This composite model is considered to be the study's chief contribution and a significant advance over other "mental models, based on the mixture of incomplete information and intuition."[21] The authors acknowledge that their study is also based on partial knowledge but claim that this is no handicap for them because they are only interested in the broad behavioral modes of the world system.[22] And, for such a purpose, it is claimed, "information now available is sufficient to generate valid basic behavior modes for the world system. The model's feedback loop structure is a much more important determinant of overall behavior than the exact numbers used to quantify the feedback loops."[23] The numbers, it is asserted, may affect the rate of growth or the time span over which a collapse occurs; the numbers cannot, however, alter the basic growth or decay modes of the model.[24]

To study the behavior of the five variables interacting dynamically with each other, the study carries out several computer runs under various assumptions. The "standard run" is made under the assumption that "there will be no great changes in human values nor in the functioning of the global population-capital system as it has operated for the last one hundred years."[25] The standard run exhibits the growth-overshoot-collapse mode for population, food and industrial capital. That is, these variables continue to grow even after they surpass the limits of the model, after which the insufficient base catches up with them, so to speak, causing them to fall far below their

19.G. Evelyn Hutchinson, "The Biosphere," 233 Scientific American (Sept. 1970) 45 at 53; also quoted in Meadows et al., n.2 at 78.

20.Mesarovic and Pestel, n. 4 at 32-55, especially at 55.

21.Meadows et al., n.2 at 27-28, 129-30.

22.Ibid., at 99.

23.Ibid., at 127.

24.Ibid.

25.Ibid., at 130.

peak values. The general time plot of the variables takes the shape of a skewed bell curve. Collapse in this model occurs because of the depletion of nonrenewable resources, and takes place — in the model — "*well before* the year 2100."[26]

Even tinkering with this standard model by assuming, in turn, (1) double the 1970 resource base; (2) strict pollution controls and "unlimited" resources; (3) strict pollution controls, "unlimited" resources and increased agricultural productivity; (4) strict pollution controls, "unlimited" resources and "perfect" birth control (where no unwanted children are born); and, (5) strict pollution controls, "unlimited" resources, increased agricultural productivity and "perfect" birth control, does not solve the essential problem of the constraints placed by a finite world.[27]

Now, there is a school of thought composed of so-called technological optimists, who believe that energy holds the key to the world's problems and that cheaper energy will enable recycling and processing of poorer grades of ores. Similar optimism is expressed in other areas like pollution and food.[28] Nuclear energy through fission reactors, the hope of the 'fifties and 'sixties, is no longer seen as paving the road to El Dorado; but its place is taken by solar energy.[29] The fallacy of this approach is exposed by *Limits*. For, assuming the resource problem to have been solved — by doubling the resource base and by assuming reclamation and recycling programs that reduce the input of virgin resources to a fourth of that used in 1970 — does not enable unlimited growth in population, food and industrial output to occur.

All the five models mentioned above exhibit the same behaviour: exponential growth of population and industrial capital, an overshoot and a collapse.[30] In the first of the five cases it is the super-exponential growth in pollution that brings about the collapse in the model; in the second it is a shortage of food; in the third, excessive pollution[31]; in the fourth, food shortage; and in the fifth, a combination of resource scarcity, pollution and food shortages.

Having presented this none-too-bright picture, *Limits* suggests that the solution to the world's predicament lies in achieving a state of

26.Ibid., at 132. Emphasis added.

27.Ibid., at 140-48.

28.H.E. Goeller and Alvin M. Weinberg, "The Age of Substitutability," 191 Science, 683 at 688-89; and below, pp. 114-115. The Executive Director of the UN Environment Programme has expressed optimism about world food prospects: See UN Chronicle (Mar. 1976) 44 at 45.

29.Ibid., at 683, 688; Mesarovic and Pestel, n.4 at 139-40.

30.Meadows et al., n.2 at 149.

31.Although pollution controls are assumed and the pollution from each industry or firm is kept low, the total pollution resulting from the increased industrial and agricultural activity is high enough to generate the collapse of the model.

global equilibrium — a state of reasonably constant population and industrial output characterized by *deliberate checks on growth* and built around the principle of learning to live with environmental limits rather than fighting them.[32] Mankind, we are told, faces a novel situation — one in which it may for the first time overshoot the finite dimensions of the globe and thus bring untold misery upon itself. And the recommended road, therefore, is to recognize and accept these limits.

In contrast to *Limits*, which takes an undifferentiated view of the world, *Mankind* builds its world model in terms of ten interdependent subsystems or regions. The regional systems "are represented in terms of a complete set of descriptions of all essential processes" — including the physical, ecological, technological, economic and social — which determine the evolution of the regions.[33] The regional approach of *Mankind*, adopted because "the world community consists of (distinct) parts whose pasts, presents and futures are different," certainly is a significant improvement over the aggregated view offered in *Limits*.[34] The descriptions of regional development processes are set up in a five-tier hierarchy: (1) The environmental stratum, including geophysical and ecological processes; (2) the technology stratum, including all human activities "from agriculture to satellite communication"; (3) the demo-economic stratum, including all accounting systems to keep track of demographic and economic processes; (4) the group stratum, including institutional responses and societal processes of mankind as a collectivity; (5) the individual stratum, including man's psychological and biological makeup.[35]

This complex model is then used as part of a technique called "scenario analysis," in which various sets of assumptions of events and choices (scenarios) are introduced into the model to predict the evolution of the scenarios and thereby yield an assessment of the possible evolution of the regional and world systems.[36]

32. Meadows et al., n. 2 at 163-88. Limiting his discussion to economics, Kenneth Boulding has called such an economy a "spaceman economy," in contrast to the "cowboy economy" which is characterized by a "reckless, exploitative, romantic and violent behaviour." "The Economics of the Coming Spaceship Earth," in Henry Jarrett, ed., Environmental Quality in a Growing Economy, (Baltimore: The Johns Hopkins Press, 1966), 3; reprinted in Alain C. Enthoven and A. Myrick Freeman III, Pollution, Resources and the Environment, (New York: W.W. Norton & Co., 1973), 14 at 18-19.
The idea of equilibrium is seen in some quarters as a subtle attempt on the part of the developed nations to perpetuate their "have" status. See, for instance, Miguel A. Ozorio de Almeida, "The Confrontation Between Problems of Development and Environment," 586 International Conciliation (Jan. 1972), 37 at 43.

33. Mesarovic and Pestel, n.4 at 36-38.

34. Ibid., at 39-40, 202.

35. Ibid., at 41-43.

36. Ibid., at 34.

An illustration will perhaps aid the reader in following the methodology of *Mankind*. Let us take the question of the economic gap between the "have" and the "have-not" nations, the substance of the so-called North-South conflict. The "standard" scenario depicts how the gap would change over a fifty-year period "if the historical pattern of development were to prevail."[37] As may intuitively be expected, the standard scenario shows an increasing gap between rich and poor regions, the actual magnitude of the gap depending on the regions being compared.

To study the effort needed to narrow the gap, the second scenario assumes certain targets: for instance, reducing the gap in per capita income between the South Asia region and the Developed World region from the present 1:20 to about 1:5 by the year 2025.[38] According to the model, the effort needed to achieve this and similar targets for other developing regions amounts to an accumulated development-aid figure of $7200 billion over the fifty-year period from 1975 to 2025. This level of aid would also lead to an average loss of $3000 in per capita income in the developed region from the level it would attain without the aid effort.

For comparison, other runs are made under new assumptions but keeping the same targets as in the second run: the present pattern of development continues till the year 2000, after which the effort is made to reach the targets of the second scenario by the year 2025; an increased amount of aid is provided from 1975 to 2000 so that no aid is needed after that time to reach the targets of the second scenario.[39] The results show that the fourth scenario achieves the targets with the least amount of aid — but it is a staggering $2500 billion over the years 1975-2025.[40]

The scenarios painted by *Mankind* are thus about as gloomy as those portrayed in *Limits*. But, while *Limits* expressly recommends checks on growth, *Mankind* advocates "organic growth." Organic growth, or "growth with differentiation," is a concept borrowed from biology and "refers to the specialization of various parts of an organic system and to the functional interdependence between its constituent parts in the sense that none of them is self-contained but rather each has to fulfill a role assigned through historical evolution."[41] Each part of the world, we are told, "has its own contribution to make to the organic development of mankind," so that "the growth of any one part depends on the growth or non-growth of others."[42] The report

37. Ibid., at 57.
38. Ibid., at 58, 60.
39. Ibid., at 60-63.
40. Ibid., at 63.
41. Ibid., at 5. See, in general, 1-9, 146, 154.
42. Ibid., at 5.

acknowledges that "the organic growth of mankind is *not* inherent in the present trend of world development," but hopes that the transition will evolve out of necessity.[43]

It is interesting to note that despite their differing approaches and perspectives, both *Limits* and *Mankind* come to substantially the same conclusions: that we are indeed confronted with global crises, that the solutions to the crises cannot be achieved by traditional means but only by developing new forms of thought based on "basic changes of values and goals at individual, national, and world levels;" that "an attitude toward nature must be developed based on harmony rather than conquest;" and that *action toward these ends must be initiated with the utmost urgency*.[44]

Some Criticisms

Limits itself points out some of its shortcomings. For instance, the model aggregates the whole world for five variables and thus, "the conclusions of the study, although valid for our planet as a whole, do not apply in detail to any particular country or region."[45] Different peoples are at different stages of development and we would need to tailor decisions and actions to suit the individual needs of each nation, and sometimes even to the particular needs of specific regions within individual nations. *Mankind* is aware of this and starts out with a regional approach, which, it is claimed, can be applied to the national level. It thus avoids the major criticism made of *Limits*. The point is important because mankind's predicament cannot be allowed to sanctify universal solutions which may have the effect of freezing the poorer peoples in a state of economic serfdom and misery.[46]

The two studies also illustrate the oft-repeated truism that computers are only as good as the data and the programs used, and that their results reflect the biases of the researchers.[47] *Limits*, for instance, assumes that world growth is and will continue to be exponential, that exponential growth cannot be sustained indefinitely in a finite world, and that sooner or later the limits to growth must be reached and surpassed. Collapse becomes inevitable. This assumption may be

43. Ibid., at 7-9. Emphasis in original.

44. Ibid., at 54, 143-48; Meadows et al., n.2 at 194-98. A similar message has been sounded by British economist E.F. Schumacher in his book, Small is Beautiful (New York: Harper and Row (Perennial Library), 1975).

45. Meadows et al., n.2 at 192.

46. Ibid., at 197-98; "The Founex Report," 586 International Conciliation, 7 at 10 and ff.; De Almeida, n. 32 at 37 and ff. especially at 48, 51, 54-56; Wilfred Beckerman, Economic Development and the Environment: A False Dilemma," 586 International Conciliation, 57 at 57, 65 and ff.; Gamani Corea, "Development Strategy and the Environment Issue," 586 International Conciliation, 78.

47. See review of Limits, by Peter Passell, Marc J. Roberts and Leonard Ross in The New York Times (2 Apr. 1972), Book Review Section, 1. Their comment on computer processes in general is "Garbage in, garbage out."

eminently reasonable. Yet, it is little wonder, then, that all the models in *Limits* end in a state of collapse; that is, all save the one in which growth is hypothetically supplanted by equilibrium.

Another criticism of *Limits*, one that has been acknowledged by the study itself and by the Club of Rome, is its neglect of social and political factors which could create dislocations and bring about a collapse of population and industrial output much before the physical limits of the ecosphere are reached.[48] This drawback is corrected in *Mankind*, we are told, which supposedly provides for the "organic socio-political-economic coupling" ignored in *Limits*.[49] That claim is not substantiated, at least in so far as the recommendations of *Mankind* are concerned. We have already referred to the suggested amount of economic assistance necessary to meet certain targets,[50] a figure so high that it is likely to raise nothing more than eyebrows in the donor capitals of the world. In another area — energy — *Mankind* proposes that the impending oil shortage be alleviated by adopting the following strategy: In the short term, the oil-exporting nations keep up oil flows "to maintain the socio-economic stability of the oil-importing regions," while the latter develop alternate sources of energy, particularly solar energy. "In exchange for their (present) cooperation, the oil producers are guaranteed a permanent role in the energy supply industry in the post-oil era." In the long term solar energy will be harnessed and "the necessary solar energy farms are built in the oil-producing regions,"[51] since the climate (desert) is particularly appropriate.

It hardly need be emphasized that the proposals of *Mankind* — even if they are otherwise feasible — bear no relation to the politics of the world, its regions and nations as played out in the 1970s. One must be blessed with an irrepressible and cast-iron faith in the foresight and fraternal spirit of mankind to believe such solutions politically acceptable. But what may be worse, by suggesting that its solutions are the *only* feasible ones, *Mankind* may in fact encourage reckless and self-defeating policies: A developed-region politician may well argue that placing the world's solar-energy farms in the Mideast is too high a price to pay for meeting the world's energy requirements, and that the goal of world energy sufficiency is therefore not worth striving for.

It may be pertinent here to examine the argument that other prognostications of disaster have been made before, but have not come true. Human ingenuity, or the plain art of muddling through,

48.Meadows. et al., n.2 at 190; Mesarovic and Pestel, n.4 at 204.

49.Mesarovic and Pestel, n.4 at 204.

50.Above, p. 10.

51.Mesarovic and Pestel, n.4 at 137-40.

have been credited with the world's survival. And these are supposed to keep working inexorably, overcoming future crises too. Earl Cook has persuasively argued that chief among the factors that have enabled the world to continue consuming more and more nonrenewable resources in the face of warnings of the exhaustibility of such resources has been the falling cost of energy.[52] Now, however, energy costs have risen dramatically and alternative sources of energy — solar or the breeder reactor — still present technological problems. British economist Edward Schumacher has thrown much light on this area. For Schumacher, natural nonrenewable resources are "capital," which is not expendable and can be squandered only at a very high cost, perhaps at the cost of life itself. "The modern industrial system," Schumacher says, "consumes the very basis on which it has been erected."[53] Here then lies the explanation for the past "successes" that have seemed to give the lie to predictions of disaster. The successes have been achieved at the cost of eroding the resource base — the "capital" — of the world society. If Schumacher's analysis can be taken as an adequate explanation of the past, then the unavoidable conclusion seems to be that the world's profligate life style must end when so much of its "capital" has been consumed that the remainder is insufficient to sustain that lifestyle. The irony then is that the very actions that have helped avert past global crises have sowed the seeds of future crises. For in surmounting past problems through increased consumption, and thereby eating into the world's capital, consumers have depleted the resources of the future. This argument seems particularly relevant now, when the exhaustion of the oil resources of substantial regions of the globe seems imminent.

The Resources Problem

Many of the arguments against the ideas espoused in *Limits* and *Mankind* isolate single variables and treat these *ceteris paribus*. Piecemeal approaches, however, miss the main point of the "world problematique," which is that while each variable and region considered on its own may seem manageable, it is the unchecked growth of several variables and regions that approximates the world's situation and is therefore germane to the discussion.[54]

The possible exhaustion of some of the more important resources is a case in point.[55] Virtually every discussion of the depletion or

52.Cook, n. 11 at 682. See also, Mesarovic and Pestel, n.4 at vii, 10-11, 31, 71.

53.Schumacher, n. 44 at 13-22, especially at 20.

54.These are called the "outer limits" in Mankind, Mesarovic and Pestel, n.4 at 1-c and ff. In contrast, the "inner limits" are the mental and psychological limits "within man." Ibid., at 151-52.

55.It has been argued that "of the 13 most widely used elements, only extractable (fossil) fuels and phosphorus are not essentially inexhaustible." Goeller and Weinberg, n. 28. Their

exhaustion of resources assigns a pivotal role to technology and the availability of cheap energy.[56] It has also been recognized that the environmental effects of resource exploitation may place a limit on that exploitation.[57] But even these limited attempts to examine more than one variable at a time are not the rule, and as recently as 1973 an American commission found it necessary to emphasize that "material resources and environmental quality are both affected by the lack of consideration of the two as a unit."[58]

Since the question of resources has figured prominently in the growth-no-growth controversy, it may be pertinent to look into the question here. In discussing natural resources it is perhaps more accurate to speak of the limits of exploitability than of the exhaustion of the resource. One expert finds that limits to exploitability of a resource may arise in at least three different ways: (1) a limit imposed by entrepreneurial and energy costs and profits; (2) the limit placed by the availability of a cheaper substitute; (3) the limit placed by a society unwilling to pay the social cost of exploiting a resource even if the operation is profitable entrepreneurially and in energy costs.[59] Thus, substantial amounts of a resource may exist but be unexploitable, and the limits need not arise from the exhaustion of the resource in nature.[60] Technology plays a crucial role in this determination, however, and it is possible for a new technology to make available resources which previously were not exploitable, thus, in a sense "creating" resources out of waste.[61] In the case of copper, for instance, technological advances and price increases have brought into the exploitable range increasingly poorer ores.

The technological optimists — "cornucopians" in one view, as opposed to "catastrophists"[62] — believe that technology will overcome; or, in cautious formulations of the same belief, that the problems are "at least in principle . . . solvable."[63] The brash

agrument is based on a computation of the total estimated quantities of the various elements in the earth's crust, the sea and the air. Ibid., at 683 and in Table 3 at 685. It seems, however, that this is a gross exaggeration of the reserves that may be available to the world in the foreseeable future On this see, Boyd, n.1.

56.See, among others, Philip Abelson and Allen L. Hammond, "The New World of Materials," 191 Science, 633; Boyd, n.1; Earl T. Hayes, "Energy Implications of Materials Processing," 191 Science, 661; Cook, n.11.

57.Abelson and Hammond, n.56 at 634; D.B. Brooks and P.W. Andrews, "Mineral Resources, Economic Growth and World Population," 185 Science (5 July 1974) 13; Richard A. Carpenter, "Tensions between Materials and Environmental Quality," 191 Science 665.

58.Material Needs and the Environment Today and Tomorrow, Report of the National Commission on Materials Policy, (Washington D.C.: US Government Printing Office, 1973), at 6.

59.Cook, n. 11 at 677.

60.See above, note 11. See also, Goeller and Weinberg, n.28.

61.Cook, n. 11 at 678.

62.Goeller and Weinberg, n. 28 at 683.

63.Abelson and Hammond, n.56 at 634.

elements of this school heap ridicule on the idea that "we shall run out of resources;" and with a complacency firmly anchored in faith assure us that "even if, one day, supplies of certain physical resources were completely exhausted, economies would long before have adapted themselves to quite different technologies."[64] Faith, however, is something that one either has or doesn't have, and an agnostic can derive little comfort from the faith of a true believer. Thus, while technology — which itself has been called "the inexhaustible resource" — may hold the key, it is by no means certain that it will be able to open all doors that mankind may be slowly but inexorably shutting.[66] Indeed, at least one expert finds that there have been "no technological breakthroughs of the kind that would give (a winning edge to) the argument that depletion continues to be shifted forward in time . . ."[67]

Even if the argument of guaranteed technological breakthroughs is set aside for the moment, it is by no means certain that businessmen will embrace and implement whatever new technology is developed. According to one writer, ". . . the basic materials industries in the United States increasingly tend to resist technological innovation" because high-risk inventions are seldom adopted in narrow-profit-margin industries that would consequently face "unmanageable capital replacement problems."[68]

The classical economic retort to such an argument is that price rises will set "in motion a whole chain of economic adjustments,"[69] but as Franklin Huddle points out, when firms are already operating close to the margin, the "adjustments" are likely to be made through the firms' closing down.[70]

One other factor must be noted: time. Even if it be conceded that with sufficient resources there is hardly a technological problem beyond human ingenuity — a proposition that ought to be taken with a large pinch of salt — it is still by no means a foregone conclusion that the new technology will be developed and implemented before, or when, the need for it arises.[71] Thus, even if it is granted that new

64. Beckerman, n. 46 at 68-70. See also, Boyd, n.1 at 650-51.

65. The term is attributed to geologist T.B. Nolan; Cook, n.11 at 678.

66. At least some technological optimists are driven into a frenzy by such skepticism. See, for instance, "Changing Limits," n.5, p.59 cols. 6-8.

67. Hans H. Landsberg, "Materials: Some Recent Trends and Evidence," 191 Science, 632 at 637.

68. Franklin P. Huddle, "The Evolving National Policy for Materials," 191 Science, 654 at 657.

69. Beckerman, n. 46- at 69.

70. Huddle, n.68 at 657. See also, Boyd, n.1 at 652 where he argues that sudden and spasmodic application of capital to resource exploitation could cause serious dislocations and damage to society. Boyd emphasizes the need to deliberate and plan in advance rather than let things slide as is the current mode of operation. Ibid., at 652-53.

71. Meadows et al., n.2 at 190-91; and Robert A. Huggins, "Basic Research in Materials," 191 Science, 647 at 647. See also, Abelson and Hammond, n. 56 at 633; and Mesarovic and Pestel, n.4 at 120.

technologies can be developed, it is entirely another question whether they will be developed, accepted, implemented and become effective before severe deprivation and dislocation occur.

This discussion of resources would be incomplete without a reference to energy. It is common knowledge that the extraction, processing and refining of minerals consumes energy, and that for a given technology, the leaner the ore, the more the energy that has to be expended to obtain a given quality of mineral.[72] This concept actually consists of two separate propositions. In the case of oil they have been described as follows: First, the costs of finding and recovering crude oil rise *exponentially* with depletion; and second, once a well has been tapped, the energy costs for an incremental recovery of crude rise in a *steeply exponential* fashion.[73] Similar considerations apply to the exploration and exploitation of other resources once richer lodes are exhausted. The problem then turns, in part, on whether "man finds an inexhaustible nonpolluting source of energy."[74] Fossil and nuclear fuels are unlikely to meet both requirements, particularly when one generates significant problems of waste disposal and thermal pollution. Only solar energy holds out hope as the "ideal" energy source; but the technological and cost difficulties today indicate that it is still some way from fulfilling the hope placed in it.

There is no question that nonrenewable resources are being depleted — some to dangerously low levels. The question is whether technology will find adequate solutions, and whether these solutions will be implemented soon enough to enable the world to avoid possible disaster. It is little wonder that most people place no more than a guarded, cautious hope in technological breakthroughs — not only in energy and resources, but also in food, birth control, pollution control and other areas.

Some Implications for the Third World

We have thus far conducted the discussion on a general plane. It is time now to attempt to draw some inferences, understanding that extrapolating from conceptual models to the real world is often a hazardous task. Let us start with *Limits* and its model projections of an end to growth on this planet within the next century.[75] If such

72. Abelson and Hammond, n. 56 at 633; Hayes, n. 56 at 661, 664; Cook, n.11 at 680.

73. Cook, n. 11 at 680-81. As a consequence of the first proposition, Cook asserts that price increases will almost certainly not bring commensurate responses in production. As for the second proposition, wells usually release crude oil under pressure. The same pressure, however, forces some of the crude into pores and pockets in the surrounding rock structure of the earth's crust. This residual crude can be tapped by injecting high pressure steam or water into the well. What the second proposition asserts is that the energy costs of recovering the residual crude increase exponentially, thus making the operation uneconomical beyond a point.

74. Goeller and Weinberg, n. 28 at 688-89; Hayes, n. 56 at 661; Cook, n.11 at 680.

75. Above, pp. 7-8.

stagnation were to occur, it is plausible to assume that it would not occur all over the world suddenly and simultaneously. The cessation of growth would likely occur initially in isolated patches of the globe, while the rest continued to enjoy some growth in population and industrial capital. As time passed on, these patches of stagnation would perhaps spread, progressively reducing the portions that still enjoyed growth. Ultimately, at the end of the model's time projection, growth in most parts of the earth would cease. Growth might be sustained only in isolated places; others would probably undergo a collapse of population and capital.

If growth in population and industrial capital is to cease anywhere, it is most likely to be in those parts of the world deficient in the elements of growth — the human and natural resources. With some exceptions, most of these regions are considered part of the Third World. If we transpose the projections of *Limits* to the "real world", we arrive at the proposition that cessation of growth is likely to occur first in portions of the Third World — an unspectacular result that could perhaps have been arrived at intuitively. Within the Third World it is possible to use the same reasoning to narrow down the likely areas of initial stagnation to those states which are the poorest in natural and human resources.

According to *Limits*, global growth declines to zero sometime during the next 130 years even under optimistic assumptions regarding new technologies, resources, and the like. Now. while it may take several decades for large portions of the globe to be sucked into stagnation, the process itself may start much earlier in some areas. And this brings us to the proposition that we may well be witnessing the incipient stages of this process in some parts of Africa and Asia at the present time.[76] A second proposition, and one that we may well shrink from considering, is that within the next several decades the stagnation may spread to substantial portions of the Third World and collapse may set in some parts. These conclusions are strengthened by *Mankind*, which reiterates the urgency and the astronomical magnitude of any effective rescue effort.

Now, if the Club of Rome holds little real hope for the Third World, we may be tempted to look to its critics for a more heartening picture. Unfortunately, there is a great scarcity of heartening pictures for the Third World on the international market. Traditional economists, looking to history, find that at no time in the past has there been "enough" to go around if everybody on earth was to be given the same standard of living as the richer members of the

76. Ominous signs of this appear frequently. See, for instance, **The Boston Globe** (2 May 1976), which ran two stories on mass famine on p. 53.

community.[77] And given the deplorable fact, these gentlemen argue, that "the rich will always be richer than the average," the "*only* way . . . for the poor to improve their lot is by participating in the general rise in the average income of the community, which means overall economic growth."[78] A quick glance around will show that while there has been a general rise in the average income — not to be confused with welfare — the "poor" have scarcely experienced any improvement in their lot, and understandably might tend to see such traditionalist arguments as attempts by the privileged to perpetuate the existing system and its injustices.

If the traditionalists do not hold any hope for the Third World except through the often-condemned theory of the trickling down of affluence through the increased wealth of the "haves," then what about the technological optimists, the cornucopians? It may appear, *prima facie*, that since the cornucopians see virtually no end to the resources of the earth, a gradual tilting of the division of the world's resources in favor of the Third World will alleviate its poverty and lead to development. If not on its own, then in conjunction with other measures such as birth control, technology transfer, education and economic assistance. This bright picture is blighted by several considerations. First, it must be noted that the technological optimists do not postulate a limitless reserve of resources *per se*, but rather believe that new technologies will extend the exploitability of ores and spur recycling and substitution.[79] Further, rising costs, it is argued, bring new opportunities for using costly technology and thereby spur its development.[80] The rising costs that spur the expensive technology, however, also increasingly drive such technology ever further from the reach of the Third World. Even if one assumes the easy transfer of new technologies, it is now known that this will not always overcome other obstacles — as the limited success of the "Green Revolution" demonstrates.

Another pertinent consideration is that depletion of the world's resource base has led states to retreat behind national boundaries and undertake steps aimed toward self-sufficiency[81]— a kind of siege

77. Beckerman, n. 46 at 68-69.

78. Ibid., at 69. Emphasis in the original.

79. Landsberg says that the "available statistics reveal no upswing in recycling up to now . . ." n. 67 at 639. As for substitution, one of the more interesting ideas to date has been to replace nonrenewable materials with renewable ones as far as is possible. But here too, according to a couple of experts, hardly any steps have been taken to develop potentials. See, J.S. Bethel and G.F. Schreuder "Forest Resources: An Overview," 191 Science, 747 at 752. See also, Landsberg, n. 67 at 639.

80. Abelson and Hammond, n. 56 at 634.

81. Ralph C. Kirby and Andrew S. Prokopovitsh, "Technological Insurance Against Shortages in Minerals and Metals," 191 Science, 713; Boyd, n.1 at 651-52; and Huddle; n. 68 at 657-59.

mentality. In such a situation, a considerable portion of the effort spent in overcoming limits is likely to be devoted to the specific needs of individual nations, with little, if any, being spared for aiding others. Autarchic tendencies do not seem to mix very well with international cooperation.

It thus appears that while technological innovations may aid the industrialized portions of the world to transcend the finite limits of the globe, the same can by no means be said of the developing parts of the world.

Conclusions

It is considerations of this kind that compel radical solutions. One such solution is the attempt to establish a "new international economic order."[82] Another is the idea espoused in *Limits*: learning to live with and within constraints instead of perpetually struggling to overcome them.[83] A third is the concept of organic growth outlined in *Mankind*.[84] The concept of an ingenious man outwitting Nature and battering down her barriers may have been useful as long as there were unconquered and unexploited horizons. That idea may have outlived its utility now that mankind is close to bumping Nature's limits. It may be time to turn the very ingenuity that aggressively extended the domain of the human race to virtually every corner of the globe to the task of consolidating that expansion, and of aiding people everywhere to live in harmony and in reasonable comfort within that domain. And the time to do that is now. This view has received wide recognition; and yet it seems to be idle speculation to hope for determined and concerted action, not merely "to do something," but to effect the necessary, fundamental, and far-reaching changes in the world order. The political and emotional solidarity that would be needed to begin such a revolution seems conspicuously absent. The odds, it seems, are stacked heavily against the vast majority of mankind.

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82. See the "Declaration on the Establishment of a New International Economic Order," General Assemby Res. 3201(S-VI) adopted 1 May, 1974, GAOR, 6th Sp. Sess., Supp. No. 1(A/9559), 3; and the "Charter of Economic Rights and Duties of States," General Assembly Res. 3281 (XXIX) adopted 12 Dec., 1974, GAOR, 29th Sess., Supp. No. 31(A/9631), 50. Mankind also advocates a new world economic order; Mesarovic and Pestel, n.4 at 143.

83. Above, p.8.

84. Above, p.10.