

THE IPAT EQUATION, GLOBAL MODELING & THE SEARCH FOR SUSTAINABLE DEVELOPMENT



How do population, affluence and technology combine in a single algebraic expression of human impact on the environment? One answer is the IPAT (Impact= Population X Affluence X Technology) equation.

In the following review of the literature, Devin Nordberg outlines elective affinities (and inconsistencies) between selected approaches to sustainable development. Devin analyzes contributions by Richard Falk, Johan Galtung, Paul Ehrlich, the Club of Rome, Saul Mendlovitz and others.

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by Devin Nordberg

Like most animals in a closed biological system, humans are overpopulating the earth and undermining the very resource base that we depend on for survival. Breeding and consuming instinctually has worked fine for us as long as the earth remained boundless for all practical purposes, but this era has come to an end. Indeed, one might even go so far as to say that the most crucial project of humanity is to prove that we can sustain a stable population peacefully in a closed, finite environment, proving Malthus wrong once and for all. Futurists and Green thinkers have been among the first to really come to terms with the need for people to adapt to a finite planet, the limits of which have only become obvious in the last generation or so.

But we are still far away from making the changes necessary to deal with this reality, and our institutions are proving difficult to modify quickly or completely enough to bring ourselves into some sort of harmony with the earth.

One of the most hopeful developments in humanity of late has been the increasing popularity of the idea of "sustainable development." In contrast to the cancerous, grow-or-die structural imperatives of global capitalism, sustainable development prioritizes living, producing, and consuming in a way that the earth can support indefinitely. For starters, our exponentially expanding population, pollution, and resource usage will have to be brought to heel. Harder yet will be keeping these activities at a level below the earth's "carrying capacity," with the concomitant need to plan ahead rather than bounce from global crisis to global crisis, adjusting and compensating for them as we go.

Clearly, the priority of sustainable development calls for a major alteration of the status quo, which means that it will have to battle the institutional inertia that surrounds us and routinely dissolves forces for change. While progressive ideas often become diluted or co-opted, losing their subversive power (e.g. "environmentalism", which has forced others to retreat to the term "ecologism" in order to call for real change), sustainable development has so far been remarkably resilient in this regard. The United Nation's World Commission on Environment and Development (the Brundtland Commission) defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Our Common Future, 1987, p. 89). This idea is turning into common parlance, but there is a great need for research that helps define exactly what needs to be done in order to meet the goal of sustainability.

In this paper I shall present, describe, and critique two methodologies used in futures studies: the IPAT equation and Global Modeling. I will be exploring these methodologies primarily to examine how they can help us understand just what is required by us to achieve a state of sustainable development, and how they can motivate us to avoid the crises that await if our consciousness (and corresponding action) in these matters does not surpass that of rabbits.

The IPAT Equation. The IPAT equation starts out as a rather simple method of assessing the environmental impact that we have on the planet. This acronym stands for the equation: $\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology}$.

As a baseline for comparison, we set all the terms to 1, so that $I = 1 \times 1 \times 1 = 1$. In "Alternative Images of a Sustainable Future," Robert Olson writes:

A total environmental impact (I) of 1, based on current levels of population, affluence and technology, is considered far too high by scientists who study the environment. Impacts such as greenhouse gas emissions, air and water pollution, soil erosion, deforestation, habitat loss, and species extinctions all need to be reduced, bringing the total environmental impact (I) well below 1 (p. 157).

Paul Ehrlich and other environmentalists use this formula to demonstrate the impacts that a growing population imposes on the planet. For example, even if you cut human affluence (A) in half, a doubled population completely neutralizes any environmental impact reduction that this sacrifice would bring. Moreover, Ehrlich suggests that this formula is a slightly optimistic simplification, because P, A, and T are not independent of one another. If our impact on the planet is too high, than any increases in resource use (A or T) have an impact that is more than a linear increase in one of these variables. In *Healing The Planet*, Ehrlich writes:

To see why, consider the natural tendency for people to use easily accessible resources first. Resources to be used by each additional person must on average be mined deeper (or extracted from poorer ores or forests with smaller trees), transported from more distant sources, grown on land requiring more mechanical cultivation, irrigation, more synthetic fertilizers or pesticides, and so on. Each person added to the population thus ordinarily has a disproportionately heavy impact on the environment compared to that of those who came earlier" (p. 7).

Unfortunately, as with any quantitative measurement that tells us something interesting, there are some tricky aggregation and definition problems with the variables involved. How can you measure affluence (A) or technology (T) in a countable way that tells us how hard it impacts on our environment? Let us assess and clarify these variables one at a time, starting with affluence.

Problematically, Olson's measurement of affluence in his comparison of different images of the future initially uses money (GWP, GNP, etc.) for (A). This is clearly insufficient, as the flow of dollars have no necessary relation to environmental impact. While some societies use money for the purchase and consumption of solid goods like food, fuel, and such, others spend a significant percentage of money on services and very ephemeral entertainments. So if money is an unreliable indicator of environmental impact, what would work better?

In describing other images of the future, Olson utilizes Amory Lovins' expansion of the IPAT formula to examine these components in greater detail and accuracy. He measures the environmental impact due to affluence as a product of both the capital stock per person and the flows of materials needed to maintain each form of capital. Thus, affluence (A) is measured as the product of two ratio, as in the following equation:

$$A = \frac{\text{Capital stock}}{\text{Person}} \times \text{Material throughput}$$

Person Capital Stock

Capital stock per person consists of the amount of physical goods that we own—number of television sets, cars, etc. Reducing the amount of stuff accumulated by each person reduces the environmental impact of extracting resources, processing them, and disposing of them. Material throughput consists of the rate of material flow needed to maintain the capital stock. Thus, using a ceramic plate involves a much lower material throughput than using a different styrofoam plate every day. Olson writes:

Many technological developments can be applied to reducing the material throughput needed to maintain a given capital stock. Options available include improved durability, more flexible design, higher total product quality, minimum-materials design, better materials choices, and more extensive recycling, reuse and scrap recovery (p. 161).

Not only does this expanded definition give a much more accurate measurement of how affluence results in environmental impact, it also suggests ways to lessen this effect. Now let us move on to technology.

In the IPAT formula, technology (T) is very narrowly defined, to the point that (T) is really just a measurement

of the environmental impact of energy usage. This is insufficiently defined, so Lovins expands this definition in a way parallel to affluence. He differentiates the level of efficiency of energy usage, and the environmental impact of different forms of energy production. Technology (T) is then analyzed as the product of two ratios, as in following equation:

$$T = \frac{\text{Energy}}{\text{Material throughput}} \times \frac{\text{Environmental impact}}{\text{Energy}}$$

Material throughput Energy

We can then reduce the impact of (T) in the first ratio by making our energy go farther through improved end-use efficiency (in our light bulbs and cars, etc.), conversion efficiency, distribution efficiency, system integration and process design. We can reduce this impact much further by changing from fossil fuels to renewable energy, thus changing the second ratio. We can now produce the numbers, although they still are just ratios of our current lifestyles. This brings us to population.

Population (P) seems simple enough to measure, making our current population equivalent to 1, and measuring changes in terms of a ratio to this. However, since this IPAT equation is meant to be a global measurement of environmental impact, by treating all populations as having one average level of impact (AT), we are blurring an important aspect of our global problematique. In Ehrlich's summary:

an average American has roughly 50 times the impact of an average Bangladeshi...Measured by commercial energy use, each American, on average, causes some 70 times as much environmental damage as a Ugandan or Laotian, 20 times that of an Indian, 10 times that of a Chinese, and roughly twice that of citizens of Japan, the United Kingdom, France, Sweden, or Australia...In terms of per-capita energy use, only Canada, Luxembourg, and a few oil producers are really in our league. Since the United States also has a large population, our total impact is gigantic—about 100 times that of Bangladesh (pp. 8-9).

Olson agrees:

"Those of us in the affluent, industrial nations of the North...produce most of the pollution and environmental damage, [and] we use most of the earth's resources" (p. 156).

By treating all populations equally, we obscure the fact that the United States is, in effect, the world's most overpopulated nation.

It would be interesting to see separate IPAT equations configured to compare the environmental impact of first, second, and third world nations, in order to highlight the fact that the population problems of the third world will never be significant in terms of global impact unless they succeed in coming close to emulating our resource habits.

Finally, we may discuss impact (I). By clarifying the other variables, we have made (I) as accurate and reliable a measure that we can. But what, in the end, does all the number crunching tell us? What value does (I) need to be under to insure a sustainable society? By asking that question, one highlights the limits of this method. Olson's article, "Alternative Images Of A Sustainable Future," uses IPAT to compare different societal relationships with the environment to determine which will bring a lower environmental impact. Unfortunately, there is really nothing in this formula to tell us just what numerical result we need to achieve. It is not at all exact as a comparative measure either, since without a meaningful zero the relationships between different IPAT results cannot be seen as a ratio. IPAT is an effectively simple "back-of-the-envelope" calculation that, as a rough estimate, is effective at identifying workable approaches to sustainable development.

Ultimately, this is unsatisfying if our goal is to determine more specifically what we need to do to bring our society in line with the limits of the planet. To make global estimations and global plans for sustainable development, then we need to turn to the efforts being made at global modeling.

Global modeling. The Club of Rome and the World Order Models Project (WOMP) are two major players in the most difficult task of modeling the entire world. Both of them consist of interdisciplinary groupings of scientists and social scientists who have all come together with the understanding that something is dangerously wrong with the direction in which the earth is heading. In their view, our patterns of resource use, international poverty, and structural instability suggest that we are in need of a better understanding of the crises plaguing our contemporary global political and social system. These groups are motivated by the desire to achieve a future that will be livable for their children and their children's children, which will only be possible if the world makes some specific major changes. The ambitious scope of their projects, prognosticating (but not predicting) and preaching to the entire world, is almost overwhelming. And with funding coming from sources like the Volkswagen Foundation, the Carnegie Endowment, and the Rockefeller Foundation, they almost seem like secret orders of the Illuminati. But their works drip with contagiously sincere idealism and hopeful energy.

I'll review the WOMP works first.

Richard Falk wrote *A Study of Future Worlds* in 1975 for WOMP, which was sponsored by the Institute for World Order, Inc. The general introduction is written by Saul Mendlovitz, Director of WOMP. In it, he spells out the need to look creatively for solutions to the global problematique. After identifying the four major world problems as war, poverty, social injustice, and environmental decay, Mendlovitz writes:

WOMP was not principally a 'utopian' undertaking, despite our refusal to succumb either to a complacent or a doomsday view of reality. Where our thinking is utopian, it advances what we call relevant utopias, that is, world order systems that make clear not only alternative worlds but the necessary transition steps to these worlds. In fact, each author was asked to attempt a diagnosis of the contemporary world order system, make prognostic statements based on that diagnosis, state his preferred future world order and advance coherent and viable strategies of transition that could bring that future into being. A stringent time frame, the 1990s, served to discipline and focus thought and proposals (p. xxii).

There are also two major subthemes running throughout the WOMP works: an argument for explicitly normative research, and a view to global governance as a major part of the solution to our contemporary problems. These will become apparent as I review Falk's work.

Falk's book begins by systematically listing the values that need to be implemented by "a better system of world order." (p. 11) Operationalizing WOMP's four major problems, these values are: 1) The minimization of large-scale collective violence, 2) The maximization of social and economic well-being, 3) The realization of fundamental human rights and of conditions of political justice, and 4) The maintenance and rehabilitation of ecological quality. Since these are referred to repeatedly in the book as "WOMP values," therefore, I will do the same.

Falk continues by discussing the world order system as historically based in the Peace of Westphalia which ended the Thirty Years' War in 1648 and established sovereign states as the primary unit of the world order. This logic has continued unabated right into the UN Charter. But Falk understands that nation-states are increasingly unable to cope with contemporary problems in the world order, and the great increase in transnational activities demonstrates how governments are being left behind.

Falk's next chapter is devoted to contemplating different world orders, from several examples of the past, and several possible future world order systems. Falk generates 9 principal types of world order systems, ranging from a system of world government, to an enhanced state system, to a condominium nexus of power/authority, to an anarchistic power/authority nexus. But before going on to design his preferred world polity, he writes:

Our preference model, set forth in Chapter IV, is derived from these organizational potentialities, combined with the assessment that there are no realistic prospects for a system change— as a deliberative undertaking at a given time— within the century. At the same time, as we made clear at the outset of this chapter, we reject a gradualist approach to reform as insufficient. As will become explicit in subsequent chapters, we are most optimistic about a sequence of changes that could bring about over time a dramatic and coherent set of results: first, value change via education; second, the growth of a world order reform movement via organizational activism; third, the institutional implementation of a new global consciousness via institutional innovation (p. 220).

This paragraph is problematic, but I will finish summarizing the book before evaluating its problems.

Falk's preference model of world order is much like a souped-up United Nations. It involves a World Assembly, a Council of Principals, and a Central Implementing Structure that is organized as follows, in accordance with WOMP values, as specified in the following chart:

Falk's Preferred World Order

World Security System

World Security Forces

World Disarmament Service (WDS)

World Grievance System (WGS)

World Economic System (WES)

World Monetary and Tax Policy Council (WMTPC)

World Economic Planning and Equity Council (WEPEC)

World Trade System (WTS)

World Technology Board (WTB)

World Development Office (WDO)

World System for Human Development

World Forum of Long-Range Planning for Human Development

World Forum for Human Development

World Commission and Court of Human Rights

World System for Ecological Balance

World Environment Authority (WEA)

World Forum on Ecological Balance

World Agency of Resource, Conservation, and Development Policy

The linear, bureaucratic model above is self-explanatory.

Falk follows this model up with a description of the transition process necessary to bring this World Assembly into being. This process involves "The Era of Consciousness," "The Era of Mobilization," and "The Era of Transformation" (see previous quotation). His goal (written in 1975) is to implement these changes by the late 1990s. He then discusses the world economy, the rich/poor gap, the rise of the multinational corporations (MNCs), and the future of the world economy. Falk's last chapter is devoted to discussing America's stake in global reform.

Ultimately, this model is unconvincing—a reflection of the linear, segmented approach used and of insufficient understanding of what it takes to make Falk's goals a reality. Falk's preferred future is given to us as a blueprint more than a model, which results in a system unconnected to today's world and a top down solution to the problems listed. His first failure is his inadequate understanding of the problems that WOMP seeks to address.

Using linear, bureaucratic thinking, Falk sees these four problems of war, poverty, social injustice, and environmental decay as totally separate entities. He pays lip service to their interconnection, but his World Assembly has four departments to deal with them separately. However, the inherent interconnections between these problems make them unsolvable individually, especially through a top down institution like a world government. His analysis of the structural causes of these problems is incomplete, especially when it comes to the environment. He wrote that it was "unrealistic" to expect a shift toward renewable sources of energy, and that we should expect a shift from oil over to coal and nuclear power in the future, without bemoaning the extent that this prevents the achievement of this WOMP value. Furthermore, solving ecological problems, which are holistic, cyclical, and interconnected, requires something better suited to the task than structured, segmented, bureaucratic divisions.

In addressing some of the world's problems, his global governance system takes the structural causes by the horns, like his discussion of the problems of war in the nuclear age. But the other problems, which are based closer to people's daily lives, are inadequately solved by a government that gives orders from the top and doesn't enable people to change their own lives. Moreover, there is absolutely no discussion of the possibility of democratically electing the members of this global body, and no discussion of ensuring that the nation-state participation in this government is done democratically.

Falk's disconnection between solutions and their implementation is also problematic. He "solves" all the problems with this World Assembly, and after this is blueprinted, then goes about the task of instituting it. This implementation is started from scratch at this point, after the solutions have been set. His method involves telling people about this solution, convincing them that this is the right way to go, and motivating them to make it happen. Here, for the first time, he involves people in his project. He writes:

The highest priority for transition efforts will involve orienting national elites or portions thereof to regard drastic global reform of a carefully specified character as necessary, desirable, and feasible. A second critical arena will involve the activities of various transnational elites, especially corporations, professional associations, church organizations, labor unions and liberation groups (p. 278).

Note that there is nothing written about changing the power relationships among these elites, and that the grassroots groups are mobilized only to institute something that has been decided for them.

These problems take a concrete shape when dealing with the example of the rise of multinational corporations (MNCs). He writes about their exponentially accelerating rise to prominence in the world, but does not deal with bringing them under any control beyond the regulations of the World Assembly. But without any attempt to make this world government any more democratic than current nation-states, it seems obvious that this world government will also be bought out by the MNCs, preventing any solutions to our problems. It is clear that his top-down plans, by not altering the hierarchical structure of power, cannot succeed in bringing about WOMP values.

Five years later, WOMP produced a brilliant, insightful, vastly improved work titled True Worlds, by Johan Galtung. Using Mendlovitz's same introduction, another attempt was made at bringing about WOMP values to our troubled world. This time, the author did not just take WOMP's four main problems at face value. Through

a series of different classificatory systems, he divided them up, condensed them into different groupings, and reanalyzed the structures that cause these problems in order to arrive at solutions that are much more workable.

Galtung pays a lot of attention to structural issues. He likes to combine the structure-oriented (basically Marxist) with the actor-oriented (basically liberal) because he believes that they are more complementary than dichotomous. One classification (p. 23) of today's problems looks like this:

Direct Violence Structural Violence Imbalance

within communities.....uneven accumulation ...depletion

between communitiesunlimited extensionpollution

Galtung goes on to create a subsidiary survey of world goals (p. 62) complete with antonyms (in parentheses):

Society

Actors Structures

being having relations patterns

level personal socio- equity solidarity

growth economic growth

(alienation) (misery) (exploitation) (fragmentation)

dispersion diversity equality autonomy participation

(uniformity) (inequality) (penetration) (marginalization)

relation social injustice

(social injustice)

These goals are reduced to two primary principles: diversity and equity. And using dichotomies, Galtung creates a typology of four structures:

Uniformity Diversity

Inequity I. Conservative II. Liberal

(feudal) (capitalist)

Equity III. Communal IV. Pluralist

(socialist) (communist)

Regarding this typology, Galtung writes, "Although these words have extremely rich meaning for those who developed them originally, the presentation here is in terms of more basic and naked principles" (p. 82). It is, of course, a Type IV society at which he is aiming for.

Three main themes help to bring about Galtung's preferred world:

...a change away from the capitalistic mode of production both domestically and globally, in both its private and state varieties; a change away from bigness and verticality (hierarchical structures) with regard to social organization; and a change away from too strong an emphasis on the territorial mode of organizing human society as opposed to forms of organization not based on ties to land or territory. Needless to say, these conclusions are both problematic and controversial, but I strongly feel that relatively basic changes are needed in a world as poorly handled as ours (p. 33).

The "poor handling" that he ascribes to our current world lies partly in the fact that while ecologists like me worry about future global crises from overpopulation and resource depletion, the truth is that over half our current population right now is not getting enough to eat, even though there is enough food being produced to feed everyone. This appalling injustice motivates Galtung more than some worry about future calamities.

His preferred world lacks the international exploitative relationships that pervade today's geography, but it does not look to global governance as the primary solution to international (or national) injustice. Change has to start on a small scale, with communities taking control of their lives. He envisions a world that is a smattering of varied aspects of Chinese People's Communes, Gandhian sarvodaya villages, Tanzanian ujamaa villages, Zen monasteries, diverse urban lives found in Shinjuku, Quartier Latin, and Soho, self-management models in Yugoslavia (1980), Israeli kibbutzim, and on and on (p. 88). In almost direct refutation of Falk's work, Galtung writes:

For there are problems that require global planning and execution and there are conflicts that require world articulation and resolution— although most problems and conflicts, fortunately for humankind, can be solved at lower levels, in ways compatible with ideas and ideals of decentralization and small units. Consequently, one should try to some extent to reason from the nature of the problems and the conflicts, and from the basic values, to the forms of a world central authority, not from some preconceived scheme taken from existing social repertoires (p. 343).

In working toward a world system, Galtung conceptually divides it into the territorial system and the nonterritorial system. Territorial groups are based on vicinity in geographical space, while nonterritorial groups are based on affinity in sociofunctional space (p. 305). He sees the decreasing territoriality of the world as a hopeful sign for a peaceful world system that is linked multilaterally by new transnational actors such as international NGOs. His vision of a global government is stronger than the UN, but rather than Falk's top-down model, this is based on a vast increase in bottom up participation. Democratic participation is explicitly addressed, and the global government he describes would be made up of representatives directly elected from citizens in all countries, as well as representatives elected from different NGOs that have no nation-state ties.

One primary purpose of Galtung's world system is to reign in the multinational corporations (MNCs) and subject them to democratic rule. If enough groups of people get together, Galtung argues, we can transform MNCs into globalized cooperatives who produce for basic human needs as a priority. He gives three arguments for globalizing the production of society's basic needs:

1. It may ensure rational planning in a global community based on a finite nature, including constructing economic cycles that satisfy fundamental needs and equalize benefits better than the present system.
2. It may ensure, even enforce, a form of production that does not lead to the present excessive costs in terms of depletion and pollution but is compatible with new norms of ecological balance.
3. It may detach production for fundamental needs from competition for market demand and tie it more to supply for real needs (p. 353).

While the UN conducts interventions only (and only sometimes) when national sovereignty is being disregarded, Galtung sees this as an artificially limited standard for enforcing international justice. He asks (polemically) what the UN would do if Hitler had no territorial ambitions but just wanted to kill all of the Jews that he could get his hands on, in order to demonstrate the atrocities that the UN can do very little about. He then takes this argument one step further while elaborating on his proposals:

Third-party intervention in order to prevent structural violence, not only direct violence, is bound to rise higher and higher on the political agenda. I mentioned the case of a Hitler bent on killing Jews yet protected by the

doctrine of nonintervention, if not necessarily in practice. But he might have said, 'I do not want to kill them suddenly, only slowly, by exposing them to malnutrition, protein deficiency, slum conditions, no health facilities, no education, and the most menial and dangerous work.' In that case he would only have put into words what many societies practice anyway. Why should this be less of a case for intervention? Are we bound to wait for the elite in that country or its legislative assembly to be sufficiently aroused by compassion or self-interest to change conditions?...Sooner or later the peace-keeping instrument will have to be made less biased and be directed not only against the destruction of human life in battle, but also against its destruction in slums (p. 370).

As you can see, he is constantly mixing different problems together, separating them out into different categories, uniting issues of problems with strategies for solutions, and pointing to many sources where solutions are likely to come from. In the end, he points to one overriding strategy: self-reliance. He quotes Mao Zedong's phrase, "regeneration through our own efforts." Self-reliance is the primary means by which heavily exploited third world countries can escape dependency on economic relations with MNCs that cement their poverty, with the ultimate goal of a world where "each part is a center" (pp. 398-399).

At the same time, this does not at all mean that nations or peoples should isolate themselves from one another:

The net outcome of this would be a world where each part is a center, spun together in a dense network of nonexploitative, participatory international organizations of various kinds. This would be the world of our dreams: many and smaller units (today's problem being the macro-state rather than the mini-state), woven together in a web of multilateral ties, substituting for the bilateral approach to global cohesion a much more multilateral approach. Utopian? Not at all, as this is how countries are kept together in this world-- not by counties, departements, provincias, ken, and fylker having bilateral relations, but through the integration of them all under multilateral, national umbrellas constituted by associations and organizations, trade unions, companies, and ministries; bilateralism is insignificant (p. 382).

For such an incredibly ambitious topic that amounts to basically solving all the problems of the world, Galtung does an excellent job at identifying the structural problems, and he presents viable, long term solutions with actors ready to attempt and shape these solutions for themselves. The book is so rich in insight that I have only scratched the surface here, but it is clear that it is much more complete, unified, and viable than Falk's work.

As these WOMP books are twenty and fifteen years old, respectively, we can look at how history has treated these futurists. For Falk, there has been little call for a strong world government, but many communities are gathering at the grassroots level, taking charge of their lives, occasionally in the manner that Galtung describes. Falk successfully predicted the end of the Cold War, but nobody guessed that the Soviet Union and the Eastern Bloc would collapse. For Galtung's nonterritorial actors, the internet has been a godsend that has been greatly increasing global communication at the citizen level. And while Galtung's exemplar of active peace-making, Yugoslavia, is now shattered by war, international NGO gatherings like the '92 Environmental Summit in Rio and the recent Woman's Conference in China provide a hopeful sign.

Falk's global model was almost a blueprint; Galtung's, more like a utopian restructuring. Now let us turn to another kind of global model, one that is more focused, limited in scope, and scientifically designed. For this we are led to the works of the Club of Rome.

The Club of Rome wrote *The Limits To Growth* in 1972, and revisited the same research 20 years later, culminating in the sequel, *Beyond the Limits*. Their conclusions rocked the world, and like all provocative and

challenging new ideas, received heavy criticism. Their audience oversimplified their conclusion as saying that we are headed toward global collapse; the sky is falling. But what the writers are primarily addressing is the fact that we are reaching a point where continued growth (of population, consumption, pollution) is unhealthy for our planet, and that we should start changing our habits of living toward some kind of equilibrium with the earth. Now that this message is well known, what is most interesting are the methods they used to come to this conclusion.

Using the newfound power of computers, the Club of Rome's research team created a dynamic model of the earth. They inserted over 300 variables into a flow diagram that registered multiple feedback loops, causal relationships, and flows of people, resources, money, etc. They used this model to examine what they believe to be "the five basic factors that determine, and therefore, ultimately limit, growth on this planet-- population, agricultural production, natural resources, industrial production, and pollution." (p. 11-12 1972) They then used this model to generate several possible future scenarios. Each model "run" kept track of resources, pollution, food per capita, population, industrial output per capita, and pollution. Before I detail the results of these runs, there are a few important caveats issued by the Club of Rome.

First, the results of these model runs are not predictions. They are merely extrapolations of trends that are based on the variables put into the formulae. They do not predict what will happen, only what will happen if the future is undertaken according to the stipulations of each run, which are all oversimplified and unlikely to ever happen the same way in reality.

Second, the variables are admittedly inaccurate. For variables that are unknowable in any exact sense (like the amount of natural resources), several runs are given with different estimations in order to deemphasize the importance of the exact numbers. For variables with unknowable effects (like pollution), very optimistic assumptions are made, again, to emphasize the overall dynamic effects rather than any one variable.

Third, the Club of Rome is not predicting impending doom for the human race. They are merely demonstrating the fact that continued growth on a finite planet is undesirable and ultimately impossible, and that we need to adapt to this reality. And the sooner we do, the better, because the exponential growth rates of so many facets of our society and the time delays between decisions and consequences can easily surprise us in how quickly they lead to global crises.

So let us run the model and see what happens. "The 'standard' world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system" (p. 124). All of these runs measure the main variables from 1900-2100, using historical data through 1970. For the first run, all variables grow exponentially and then diminish (including population, which starts shrinking around 2020 due to lack of food), except for resources which goes into one long tail spin. The primary cause of this overshoot and collapse scenario is nonrenewable resource depletion. We do not like mass starvation and do not think that the Club's estimates of our natural resources are accurate, so they run the model again.

The next run assumes double the natural resource base, but this time population falls around 2050, partly from excessive pollution produced by using the enlarged resource base. In addition, resources are still depleted leading to falling industrial output which causes the capital intensive agricultural sector to decline.

Another run is made, this time not only doubling the resource base, but also assuming programs of recycling and reclamation that reduces the resource needs per unit of industrial output by 75%. With practically infinite resources from very optimistic assumptions, the population still falls from sheer masses of pollution, while resources remain abundant.

Run it again, the same way as last time, but also assume the installation of pollution controls that reduce pollution per unit of industrial output to 25% of 1970 values. This time, population skyrockets, until late in the twenty-first century, the limit of arable land is reached and both population and industrial output decline. They double the average land yield in addition to everything else and run it again. But the increased industrial production that results creates a pollution crisis beyond the controls, and the intensive use of land leads to erosion and food shortages, leading to population declines again. Add "perfect" birth control that prevents all unwanted children globally to all of the other modifications, and still growth stops before 2100.

Their point, apparently, is that growth has limits. Growth cannot, and should not be the policy that our societies pursue any longer, because it leads to a scenario of overshoot and collapse, where in the process of overpopulating we lower the ability of the earth to support us, making our population crash even worse. That point being made, they spend the rest of the book attempting to find a combination of policies that results in a positive image of a sustainable society.

After several more model runs under varying conditions, they find a stabilized model where none of the major variables crash. The policies that produced this state of equilibrium are: stabilized population (where the birth rate equals the death rate) in 1975; industrial output stabilized in 1990; resource consumption per unit of industrial output reduced to one-fourth its 1970 value; prioritizing education and health facilities over factory-produced material goods; pollution generation per unit of industrial and agricultural output reduced to one-fourth of its 1970 value; capital diverted to food production beyond economic logic; capital used to preserve agricultural sector; and finally, average lifetime of industrial capital increased, implying better design and less obsolescence. In this model:

The stable world population is only slightly larger than the population today. There is more than twice as much food per person as the average value in 1970, and world average lifetime is about 75 years. The average industrial output per capita is well above today's level, and services per capita have tripled. Total average income per capita (industrial output, food, and services combined) is about \$1,800. This value is about half the present average US income, equal to the present average European income, and three times the present average world income. Resources are still being gradually depleted, as they must be under any realistic assumption, but the rate of depletion is so slow that there is time for technology and industry to adjust to changes in resource availability (pp. 164-166).

The book ends on a cautionary note. Most of the policies instituted in this stabilized model began in 1975. They give it one last run, just like this one, but with the corrective policies not instituted until the year 2000. As you would suspect, the equilibrium is no longer sustainable; before the year 2100, there are food and resource shortages.

Twenty years later, they revisited this computer model, and produced *Beyond the Limits*. This book confirmed all of the results they achieved in 1972, although finding an equilibrium was harder to achieve since we did not make much progress in this direction in those 20 years. The book also strenuously repeated the caveats mentioned above, especially emphasizing the fact that they were not forecasting "doom and gloom" (although the triumphant sounding title was meant to inform us that we were living beyond the limits already, at our own peril), but merely persuading the world to change its direction.

Of all the criticisms that have been leveled at the marvelous work done by the Club of Rome, one strikes me as particularly relevant. While the ecologist in me wants to uncritically accept the results of these works, the futurist in me is disappointed. They seem to think that increased agricultural output, recycling of resources, and "end-of-the-pipe" pollution control constitute overly generous assumptions of what technology can do to attempt continual growth. What about genetic breakthroughs, which could lead to food production that occurs independent of land at all? What about nanotechnology, which could potentially eat up pollution and turn it into valuable resources? What about closed-loop 'industrial ecologies' that prevent pollution from occurring in the first place? Certainly the exponentially growing technological power of the world will not be set back as easily as all this.

The conclusions of the Club of Rome are still completely valid, but rather than being enforced by technical imperatives, they should be justified by political values. The system of perpetual growth that drags us into the future is based on serious, structural injustices on a global scale. As long as over half of the population does not have enough food to eat, they will endorse growth in the hopes that it will relieve their misery. As long as production occurs for profit rather than for human needs, growth will continue, inimical to human values of "enoughness"

Moreover, the highly technologized world that may be able to continue growth farther than the Club's projections would be highly dystopian for the majority of its citizens. A healthy, abundant environment provides uncommodified wealth for people, allowing them to be self-sufficient and self-reliant, free to make a wide range of lifestyle choices. But imagine what it would be like to have your total survival depend on the production of food from the genetic synthesizer laboratories. The disempowerment of most citizens would certainly make democracy an endangered concept, and many people would feel a spiritual loss from being so disconnected from the lifeworld.

Work towards a state of sustainable development continues apace, building on the produce and the methodologies discussed above. And while the global crises that appear to be approaching may make us feel impatient and want to take direct action, scientists and social scientists continue to call for more and better information, demonstrating that research and writing in this field is far from an irrelevant exercise either. Indeed, it might be the most cutting edge issue we could work on these days.

In the end, however, the need for sustainable development can never be demonstrated with scientific facts, measurements, and models alone. It has to be supplemented by sociopolitical values that favor freedom, social justice, nonviolence, and self-determination.

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