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Environment—An Elastic Limit to Growth

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Does the environmental pollution accompanying demographic and economic growth require an early end to that growth? Are there measures entailing modified incentives and technological fixes that might be effective in controlling pollution? If we are to answer these highly topical questions, we need a clearer understanding of the nature and causes of environmental problems—in particular, we must distinguish the different sorts of problems we have and the kinds of solutions that are appropriate for them.

Sources of environmental problems

Population and resources always have been basic in defining the predicament of mankind. Within the limits set by prevailing human institutions and technology, the balance between resources and population has determined the possibilities for human well-being.

Environment is perceived as a newer element in this equation, chiefly because it has not heretofore been an important constraint. So long as man remained a hunter and gatherer he was dependent on and part of the natural system, subject to the same checks as other species and capable of only a minimal impact on the system. (An exception is the fire that early hunters sometimes used.) As an agriculturist man took the first steps toward permanent and often damaging alteration of the natural system. His protected herds often destroyed the natural cover, his irrigated agriculture enjoyed a cycle of fruitfulness and decline, and his cultivation of upland areas often exhausted and eroded the soil.

These were significant alterations in the natural system with locally severe consequences for other species, but they generally were limited in spatial extent. Man's numbers were too few and his technology too feeble to affect larger systems. His transport and organization limited his concentration in cities, so many of the environmental problems associated with concentration were avoided. It was only with the arrival of the industrial system, with its extensive draft on stored energy and minerals, that we made a major break with the natural system, and this break has multiplied our environmental problems many-fold. While we encountered precursors of modern environmental problems in Roman lead poisoning or in the sanitation problems of preindustrial cities, pervasive, multifaceted environmental deterioration is a creature of the industrial age.

Industrial man threatens the environment in many ways. His productive technology permitted a massive increase in numbers as he mastered ways of controlling disease and raising food output. His wants no longer are limited to biological needs but become infinitely expandable economic demands, encouraging greater use of physical materials in the system, along with their attendant residuals. Now driven by economic logic into massive urban concentrations, man's wastes overwhelm the local assimilative capacity of the natural system. Moreover, when unrestrained by regulation or incentive, technology has developed in a direction that has taken little account of the residuals generated. Even when concern is present, technology sometimes has moved at a pace that has outraced control measures. In some cases the residual amounts are so large or the materials are so strange that the natural system is unable to neutralize them, and their effects on other species or on man are either damaging or are poorly understood and fraught with danger.

The pervasive environmental effect of these changes is a recent phenomenon. The absolute magnitude of the materials throughput resulting from exponential growth of population, and especially of income, has risen dramatically in recent decades. In combination, the discharge of exotic materials poorly assimilated by the environment and the exhaustion of the environment's reserve assimilative capacity as thresholds are reached in an increasing number of cases carry the potential for disproportionately large environmental damage.

One need not be dogmatic about which of these elements contributes most to environmental problems. Clearly, they all have the potential to do so if continued long enough. For the less developed countries (LDCs), where population growth has been rapid and per capita income growth modest, environmental stress is largely a consequence of population growth, although growing urbanization and resulting localized overloads also play a key role. In developed countries, population growth is generally slower, and per capita income advances account for most of the increased material throughout. Such countries, being technically more dynamic, tend to rely on less "natural" technologies.

Some would fault technology *per se* for the environmental problems of advanced countries, exempting population and income growth from blame. However, this view commonly fails to take into account the fact that many synthetic materials are comparatively inert in the environment; hence, focus on the growth of less "natural" technology does not truly measure environmental damages. Also, they fail to consider that more "natural" alternatives to high-technology processes to serve growing population and income levels may not be viable or will have severe consequences of their own at the higher levels required.

Population has grown at 2% or more per year in the LDCs and about 1% in advanced countries. At this rate it doubles in 35 years or less in the LDCs and 70 years in the advanced countries. In view of existing age structures, abrupt cessation of such growth is nearly impossible. Even on optimistic assumptions world population is unlikely to stabilize below 15 billion in the next century, with about 75% of it in countries currently hard to put afford environmentally protective measures. Thus, from a figure of 2.5 billion at midcentury we see the prospect of a 5-fold increase in burden resulting from population growth alone.

Income grows at 4% or more per year in advanced countries. On this basis the doubling time is about 18 years or less.

The LDCs are joining this parade as well, and, while they start from low absolute levels, if they move toward their aspiration to obtain the standards of advanced countries, they will contribute an enormous added burden.

Consumption of materials that carry special environmental hazards is often faster still—farm chemicals, radioactive materials, and plastics. Recreational uses of land also grow at exceptional rates. Income growth at the rates we have come to expect is inextricably bound to technological change. Such change is labor saving, but often at the expense of the environment—e.g., chemical weeding or modern strip mining. We have very few good time series of the past condition of the ambient environment. In some local situations we have improved air quality while losing ground in others. Almost everywhere the quality of natural water declines.

The range of environmental problems

The environmental crisis is not of a single kind. We face threats of various orders of gravity, and our response should be attuned to the nature and gravity of the threat. The spectrum ranges from environmental burdens affecting our enjoyment of amenities all the way to threats to the earth's life support system. It includes those that can be cured by a cessation of the insult, as well as those that may be permanent and irreversible. It includes the immediate and the deferred, the identifiable and the barely suspected, and the highly local and the potentially global effects.

The most ubiquitous kind of environmental damage we suffer is the loss of amenity. Many aspects of air and water pollution illustrate this; we are denied the view of a clear day or the pleasure of recreational use of clean water. Damage to the landscape from mining or from ill-planned urban development fall into this category, along with much noise pollution, the dispersal of trash, our access to nature, and the like. In most of these cases the current generation collectively suffers the consequences of its acts. To be sure the incident individuals may differ, but society can assess the overall costs and benefits of its behavior to determine whether that behavior should be altered. While some changes in land use—such as wilderness invasion or defacement of landscape—may be essentially irreversible and therefore affect future generations, most of the insult that we place on the environment is visited upon our own heads in the way of damage to environmental amenities.

Effects on human health are a graver consequence of environmental pollution. They may arise from some of the same sources that cause loss of amenity. Air pollution in particular appears to damage health, and in some cases noise may also. More frightening are the insidious threats from heavy metals, radioactivity, synthetic chemicals, and possibly from pesticides. Environmental threats to health often are unperceived because they are buried in the complex exposures of modern life, have long latency periods, arise from low-level chronic exposures whose effects are difficult to establish, or occur as an added stress with different effects on susceptible individuals. An especially distressing form of health damage is the teratogenic effects of some chemicals, many of them still unestablished.

In a few cases pollution results in genetic damage or in impairment of human reproductive capacity. The most obvious example is radioactivity; it should be noted, however, that most human exposure to ionizing radiation is either of medical or natural origin. Again various chemicals, including pesticides, have been called into question as possibly either suppressing reproductivity or causing mutations.

Many environmental burdens alter the ecological balance and thereby are harmful to a particular species while favoring others. Nature constantly adds to and subtracts from the genetic pool through mutation and extinction. Man can hasten the extinction of species in drastic fashion, and irretrievable genetic information of future value to him is lost. Some have argued that man may be intervening in the great global systems—oceans, atmosphere, and soil—so as to sabotage the earth's life support system. While it is possible to contemplate climatic change or damage to the sea on a large scale, no very plausible mechanism has been suggested whereby pollution can terminate the basic life processes, whatever it does to particular species.

Means of coping with environmental problems

The foregoing categorization of environmental threats is of value in determining how we should react to the different kinds of problems. We can require less-stringent measures when dealing with damage to amenity than we could accept where the earth's life support system is imperiled. Likewise, the question of reversibility is of key importance in determining our reaction.

While the environmental crisis arises out of population and economic growth and the associated technology, damage need not parallel movements in those factors. In fact, one of our problems is that as threshholds of absorptive capacity are exceeded, damage threatens to go up abruptly. On the other hand, if we are faced with limits set by absorptive capacity, we can seek a productive system that will economize on environment. This is the essence of our control program. Most technical and economic responses of a short-term nature are aimed at diminishing the environmental burden per unit of output. Granted that longer-term growth conceivably could overwhelm such measures, those who foresee early environmental limits to growth do not appreciate the potential that abatement measures may have. If over the long term they prove insufficient to accommodate exponential growth, then more fundamental cures can be contemplated, but there is no need to surrender before the battle.

Setting environmental goals is the first stage of policy. This is a difficult process, for we have only inexact means for determining social preferences or for giving them political expression. Aware of these difficulties, economists tend to favor using the market to determine preferences; however, social choices on environmental standards often must precede, and market techniques are of greater value in implementing choices arrived at by other means. In arriving at these choices, the clearest rationale can be made for policies designed to insure against diaster involving human health and current or future permanent damage to the earth's life support system. On a current basis we determine what levels of health and amenity we choose to buy. This leads in turn to definition of the ambient standards we wish to attain and the associated discharge standards compatible with them. Our concern both for resources and environment favors increased recycling of materials. In addition to establishing our broader goals, we should aim to rationalize our technical and managerial techniques so as to insure efficiency in reaching them. All of these choices must be made in the fullest possible awareness of the trade-offs among environmental effects and between them and economic effects.

Although it is fashionable to scoff at the "technological fix," we shall indeed have to rely on technology and management techniques over the intermediate term to cope with pollution if we are to sustain growth. The measures that we may contemplate are changes in materials, processes, and products that allow us to prevent, contain, neutralize, or dilute residuals. Illustration can be had across the spectrum of industry. We make a major effort to use low-sulfur fuels at present as a means of preventing sulfur discharges. The sugar industry has provided a favorite study for environmentalists because it demonstrates that process change can drastically reduce the amount of wastes generated. Again, the paper industry provides an instance where changes in the mix of final products (reduced amount of bleaching and dyeing) can greatly diminish the generation of harmful wastes. While some types of pollution can be prevented, others—such as radioactive materials—must either be diluted or contained. Where we rely upon natural assimilative capacity, temporary containment is useful in reducing peak loads. Moreover, such capacity sometimes can be augmented (e.g., flow regulation in water courses) Neutralization is feasible in other cases, as in the treatment of acids.

While we tend to think of these possibilities as technical measures, the adoption of appropriate management techniques may be equally important. The modelling of airsheds and watersheds to determine the volume and timing of the effluents they can sustain under different circumstances is a case in point. At a still more general level, integrated planning of energy and transportation could permit us to make more efficient use of environmental resources.

What assures that we will take the necessary steps on a timely basis? Traditionally we have relied upon the political process to articulate social goals and then have sought to implement them via government regulation. We should try to improve our methods of determining social goals. Theoretically a system of vote trading among interest groups would approach the optimum result. At the same time, perhaps we should experiment with other techniques for discerning the public will.

Once collective choices have been made, there is still a question of the most effective means of implementing them. So far we probably have relied too much on regulation and too little on economic incentives. Where we are interested essentially in allocating the use of the common property environmental resources to prevent overload (i.e., within set standards) effluent charges are a useful means of limiting access. This promotes technical initiatives of the sort discussed earlier and insures that those to whom the right to discharge is most valuable will have first call. Effluent charges are not suitable in every case, for in many circumstances it is impossible to measure actual discharge. Ingenious variants on the effluent charge are possible—e.g., charges on the sulfur content of fuel burned, with rebates for sulfur recovered, or assessment of auto manufacturers on the basis of the average performance of their cars in actual use. In general, effluent charges are most useful in cases of pure congestion where discharges can be measured directly, as in industrial and municipal pollution.

Where we deal with a problem of allocating the use of a congested environemntal resource and use economic incentives to stimulate technical response, we may find that the cost of control is less than the social benefits of reduced pollution—the cost benefit standard is met. We may safely apply the standard when dealing with amenities, the costs and benefits of which fall on the current generation. Likewise, we may apply it where health effects are incident on those who must bear the cost.

In some cases, even when dealing with an allocation problem, we may not choose to assess charges because we do not approve of the distributional effects. For example, many would resist auctioning off access to the wilderness to the highest bidder.

If we face a threat that is irreversible, especially permanent damage to landscape and natural features or types of pollution that may affect the health of future generations or the quality of the earth's life support system they inherit, then we can have less room for the use of economic incentives. In these cases we are not dealing with an allocation problem for which economic criteria are sufficient, but rather with longer range values. The standard must be to minimize our damage and to weigh very seriously the economic benefits that we seek against the effect on future generations. Where irreversibilities are present, as for example in land use decisions, regulatory devices may prove more effective.

In dealing with most forms of pollution it is useful to remember that our problems are concentrated in a few sectors of the economy. If we could cope effectively with energy use and transportation problems, and a few types of agricultural pollution, we would go a long way toward curing our most aggravated environmental degradation. A few types of industry —paper, chemicals, food, some metals—also present special problems. Our energy and transport problems could be greatly alleviated by rational land planning, with further benefits for the esthetic qualities of both city and country, while still allowing more room for other species. Admittedly, this would require larger scale and more comprehensive planning than we are accustomed to, but it might also foster greater awareness of the kinds of trade-offs involved and permit technical advance to be focused where most needed.

As part of our effort to raise the level of satisfaction that we derive from a given throughput of materials, the environmental concern shares with the consumer protection movement an interest in the production of more durable and more repairable goods and the shunning of frivolous changes in tastes or of unconsidered tastes that make undue demands on the environment (e.g., perfect fruit, large cars, bleached paper).

Our problem is made especially difficult by the degree of uncertainty that attends so much of our activity. Particularly with regard to chronic effects bearing on such large systems as the global heat budget, oceans, and soil, we do not know the consequences of our actions. While it is tempting to argue that further research will dispel doubts, it is also likely that technical dynamism will be creating new uncertainties even as we get a grip on the old. Indeed, even a society that opts for population and income stability may still be technically dynamic if it seeks to increase leisure or to replace exhausted natural resources and, therefore, it will constantly be creating new uncertainty.

This uncertainty is magnified by the speed of change. Our scientific revolution of recent decades and the rapid pace at which its discoveries have been incorporated into industrial practice have given us little time to attain awareness of consequences. In any case, the consequences may be long delayed or appear only after irreversible threshholds have been crossed.

Exponential growth and limits

Recent attention to the implications of extended exponential growth is very useful in emphasizing the speed of change, though the interrelationships between the variables are far more complex than the models allow, and the models do not serve as confident predictors. Environmental limits are one of several possible constraints on growth and must be considered along with resource constraints. Many possible trade-offs are possible between population, income, resources, and environment. Restraint on population and income clearly ameliorates the burden on the environment, as well as the draft on resources.

Enormous quantities of resources are likely to be required as economies expand and the LDCs are drawn within the ambit of industrial society, but this does not necessarily imply early (next century) overall resource limitations. The possibilities for substitution among materials are great, many areas of the earth have not been fully explored for mineral deposits, and technical advance constantly brings marginal resources into the exploitable range. Energy need not be a limit if technology advances as expected. Some of the more exotic potential sources of energy, such as fusion reactors or solar energy captured outside the atmosphere and beamed in, might even carry reduced environmental hazards. The limits to expansion of food production may be encountered earlier if we rely exclusively on agriculture practiced in open fields, but other possibilities for synthesizing food may yet prove feasible.

In view of these possibilities it is not legitimate to extrapolate rates of consumption against known reserves of materials or land to arrive at exhaustion dates. It is true that we operate within a finite earth, but we have many paths of adjustment open. Some adjustments will be made naturally enough as scarcer supplies raise price, restrict consumption, encourage recycling, and favor new exploration. We could hasten this by systems of bonuses and charges if we chose. Much of what we may hope to do in the way of exploiting inferior resources or recycling materials depends on ample availability of energy. Our constraint here is less likely to be a resource constraint than the problem of limiting the environmental consequences of energy use.

Environmental limits to growth are even more nebulous than resource limits when examined closely. The pollution arising from industrial, human, and animal wastes seems amenable to technical solutions. We can protect our air and water from overload if we care strongly enough to do so. Agriculture has taken a direction that is heavily dependent on pesticides and fertilizers, both very difficult to contain. Again, we are not prisoners of this technology, given time to adjust. Most of our environmental problems from energy use arise from the combustion of fossil fuels. We are taking steps to reduce these effects, even as we also move toward substitutes for combustion. While nuclear energy presents some long-term threats form operational accidents and from radioactive wastes, the problems are as much administrative as technical. Disposal of heat from energy conversion is a local problem and conceivably could become more general in the remote future. However, we could economize on energy if it were necessary and we could turn much presently wasted heat to useful account.

Such reassurance concerning resources and environmental adequacy perforce has a timeless quality about it. The most useful function to be served by models that examine the interrelations of various limits to growth would be to provide a more realistic appraisal of the possibility of overruns leading to disaster, not because ultimate limits are reached, but rather because change occurs faster than the system can adjust.

The greatest danger of a disastrous overrun occurs in the population–food supply equation. Scarcity of other resources is not something that arrives abruptly, and if such scarcity occurs it will in any case simply slow the pace of industrial growth. Severe current burdens on the environment generally could be met by reducing output or by other technical means over a moderate time horizon.

However, the appearance of food shortages resulting from excessively rapid population growth would very likely lead to agricultural practices that would be damaging to the environment—especially since they would occur in LDCs where neither dietary shifts nor technical measures could provide early relief. For the U.S. plausible population growth rates do not threaten sudden overruns that would affect food supply. A global shortage is possible, but the fact that we are not greatly dependent on outside sources of food gives us some insulation from such an event, although we could be engulfed in the accompanying turmoil.

For the rest of the world (especially the LDCs), which lacks our reserve food capacity, our highly discretionary consumption pattern, or the technical and economic means for dealing with pollution, rapid population growth has the potential for creating severe problems. It becomes a multiplier by which all other resource and environmental difficulties are magnified. Since demographic trends have great built-in momentum, and the human life span is long, quick or painless adjustment is not available. Local conditions vary about the world; in some a population crisis already is present and in others additional population would be harmless. Rarely, however, can any positive case be made for continued population growth. Although its cessation would create transitional problems, they are of a sort that must be faced eventually in any case, and the chances of dealing with resource and environmental problems successfully—whether we face disaster or not—are greatly enhanced if we confront them at lower total population levels.

We are far from understanding the psychological and social factors that govern the desire to have children, and we should not be too complacent about the recent trend toward zero population growth in advanced countries. Such trends have turned about before.

In most parts of the world population growth operates to depress per capita income; at a given level of technical sophistication we can advance our income standard only through population restraint, or we can increase population only at the expense of per capita income. In practice we still count on productivity increases permitting both levels to advance.

In a high income country like our own, per capita income growth may seem less essential, yet it is important in providing us with a margin for coping with environmental burdens and useful in correcting remaining economic deprivation. While higher income expressed in the consumption of goods loses some of its appeal with affluence, growth could be channelled into less-noxious paths. Obvious candidates are such nonpolluting activities as sport and culture. Attention to improved product quality requiring less frequent discard and replacement also would help. The reconstruction of our cities to make them more functional also would reduce materials consumption (especially in transportation) and promote recycling (e.g., heat, sewage, solid wastes), while enlarging the human satisfactions the cities yield.

Distributional aspects of environmental quality

The environment is one of the natural resources available to man. In most of its manifestations it is a renewable resource, and the productive services it yields can be augmented and economized as with any other limited resource. Man also makes permanent changes and the environment can be an exhausting resource. When we use such natural capital, unless we convert it to other productive forms of equal value, we deprive future generations in favor of current income. We should accept some restraint to preserve the value of the legacy we leave behind.

The congestion of common property resources and the cost of counteracting added environmental burden imposes a constraint on growth. The free use of open-access resources that fueled our own development is not viable in the future. However, since the costs of transition to a new system must be met, there are important current distributional questions to be faced. The poor, whether domestic social groups or poor countries, are unlikely to rate environmental quality as high as economic advance, while the rich may take the opposite view. There is no special reason why the poor should accept their inferior position—even more so if there are true global environmental limits that impede total economic growth. The plain implication of environmental limits to growth is greater income equality.

At present, perhaps too much is being made of global environmental limits to growth and the requirements for international compensation. The underlying premise that such limits are upon us and all embracing is far from established. In fact, most environmental damage is rather local or regional in nature. Pervasive damage to global systems such as the atmosphere, climate, or oceans is hard to identify. Damage to international lakes and rivers and to regional airsheds is common, but often involves adjacent nations at a similar stage of development; such damage is amenable to bilateral or regional agreements on control and compensation. Oil spills at sea are more ubiquitous, but in this case the rich share the damage, and for as long as they control the oil trade they are best positioned to cure it. The threatened extinction of certain marine species calls for wider agreement and may require compensation for some to agree to refrain from the harvest. Eventually, the threat of pesticides affecting the ocean or damage from combustion products in the atmosphere could require costly alternatives. At that point we could expect poor countries to stake an effective claim for assistance in changing to nonpolluting technology.

Meanwhile, the effects of most environmental threats are local in nature, and those areas that generate the problem also suffer the consequences. In a world of sovereign states it is difficult to see why those countries that choose to use technologies damaging to their own ecosystems or populations in order to gain competitive advantage should be prevented from doing so, distasteful as this may seem, as long as the damage is confined. They should be made aware of what they are doing and informed of the alternatives, but they cannot be stopped, nor do they have any special claim for assistance that differs from the general obligation assumed by the rich to aid the poor. Poor countries nonetheless will assert claims against the rich for extra investment costs and for export losses incurred in pursuit of environmental measures urged by the rich, and they will expect compensation for preserving habitats for migratory birds and animals or rare species.

Summary

In sum, threats to global environmental systems do not appear immediate. Within the U.S., threats to local air and water quality often are serious and the damage to health and amenity that we incur is great. However, our technical possibilities for dealing with these is promising, provided we are able to organize ourselves so as to make choices and to implement the measures needed. Because this is a difficult task, we should make use of the full range of tools available to us.

In particular, where we deal with current congestion that can be corrected by reduction in the environmental burden, we must establish the levels that we wish to attain; we can then make much use of the market for allocating the permissible use of the receiving media. This approach will encourage technical initiative and secure a more economical cure. The common property resources also should be managed by the use of systems approaches so as to yield services consistent with the socially determined quality level.

Where environmental impacts are permanent and we are not allocating a current flow of absorptive capacity, then we must look to the rights of future generations and take an essentially conservationist view, allowing the change only if we can argue that it leaves the future no worse off. Again, sophisticated techniques for appraisal, planning (especially in regard to land use), and management may be required.

Because we will be managing long-lived, highly toxic materials or protecting large air and watersheds with delicately balanced mechanisms, a collapse of the social system could be especially catastrophic for the environment. As we design our technology and institutions for the future, great attention should be given to the need for fail-safe provision in the event of social disintegration.

This review has focused mainly on the U.S. Our resource and technical position and our demographic and economic totals are such that we can cope with foreseeable environmental problems. This conclusion would not extend to a limitless horizon of exponential growth, but it does not require early cessation of growth. As a safety factor there is much to be said for arresting population growth, since it makes all problems easier to manage.

We live in a larger world, where continued population and income growth could generate resource and environmental problems of great severity in the next century. We cannot escape these entirely. An impulse to help that simply subsidizes added population growth in the LDCs is probably counterproductive. Our best service to others may be to advance the technology and institutions needed for living at moderate density and high income, while economizing on nonrenewable resources and attaining a liveable environment compatible with the natural system.