ARE THERE ECOLOGICAL LIMITS TO POPULATION?

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Contents

Abstract

Policy on population and environment in the United States and abroad has been vacillating, unsure of its course; it would be more decisive if the several disciplines could agree on the nature of the problems and their urgency. The two disciplines principally concerned are biology and economics, and the contribution of this paper is to identify eight of the many axes or directions on which the methods and traditions of the two are different. For example, the first of the axes runs between contingency and orderly progress, with biology tending to seek out the former and economics the latter; thus biologists can more easily comprehend catastrophes, such as the demise of the dinosaurs or widespread desertification. The third axis concerns indefinite market-driven substitutability, seen by economists as resulting from scientific discovery; natural scientists, including biologists, whose discoveries make possible the substitutions, are skeptical. Axis 7 results from the fact that economics concentrates on goods that are on the market, and so deals with a truncated part of the commodity cycle, while ecology aims at the whole; because goods disappear from economic statistics once they pass into the hands of consumers many of their ecological effects are invisible. I believe that from similar further study of the two disciplines a common set of policy recommendations will ultimately emerge.

Foreword

Major problems of the world are only rarely dealt with by a single scientific discipline, and IIASA's concern with policies intended for application has forced the Institute to be interdisciplinary from the start. Our work on acid rain, on energy, and on global warming has one foot on the purely physical side – technical efficiency of our use of energy – and one on the human side – behavioral change to more efficient use or less energy-intensive activities.

The task of combining the results of the several disciplines bearing on a given question is always daunting, but it becomes especially troublesome when these come to opposing conclusions. Is population growth among the most immediate and serious threats to human welfare, or is it one of our less urgent problems? How does one make use of the results of two disciplines – economics and biology in this case – in the area of application where their conclusions are so different?

To reconcile them one must find out what principles and methods of the two disciplines underlie the difference in conclusions. The paper that follows marks an important step in this direction.

Peter E. de Jánosi
Director

Are There Ecological Limits to Population?

Nathan Keyfitz

Two groups of scholars, both well represented in this Academy, arrive at different, sometimes quite opposite, conclusions on how close are the limits set by the ecosphere to the growth of the human population and the expansion of its activities. One group, including most biologists, says, in the words of the NAS Statement of 1992, "Global policies are urgently needed to promote ... more rapid stabilization of world population." The other group, mostly economists, says "If there are limits to growth they are very wide, and until we know more there is no urgent need for policy change." I refer to the contemporary disciplines, rather than to those of the 19th century.

Both groups consist of serious scholars, and the difference on the issue of growth that has developed between them cannot be an arbitrary whim of individuals but must have roots in their respective disciplines. An outsider to both, in reading their current literature I find eight axes of difference in their methods and perspectives that help to account for their different conclusions. Anyone who wishes to draw his or her own conclusion on the population question owes it to the practitioners of the two disciplines to understand what lies behind their difference, and to this understanding I will try to contribute.

Axis 1 Economics Deals with Growth; Steady Progress as Against Biological Contingency

To the modern biologists that I read there are many possibilities at every stage of evolution, and if we have come down from the trees and arrived at a condition where we are capable of walking upright and using language, we are just lucky. As biologists look back they see nothing inevitable about it.

Stephen Jay Gould[1] finds thoroughly unacceptable the 19th-century view that the whole history of the earth has been an unstoppable march to arrive at the goal of contemporary man. "This common scenario," he says, "is fiction rooted in traditional hopes for progress and predictability." He points out that

> Mammals spent their first hundred million years – two thirds of their total history – as small creatures living in the nooks and crannies of a dinosaur's world. Their sixty million years of success following the demise of dinosaurs has been something of an afterthought. [Reference 1, page 318.]

The disappearance of the dinosaurs was by no means preordained, and if they had stayed

> mammals would still be small creatures in the interstices of their world. This situation prevailed for a hundred million years; why not for sixty million more?

He speaks of how quirky are climate and geography:

> Continents fragment and disperse; oceanic circulation changes; rivers alter their course; mountains rise; estuaries dry up. If life works more by tracking environment than by climbing up a ladder of progress, then contingency should reign. [Reference 1, page 300.]

Such uncertainty in the historical process that brought us here is conducive to a sense that the future is also uncertain, that to think our biological fate is under our control is an illusion.

This is very different from the modern economic concept of continuing growth, which sums up all that is most desirable in the rich panoply of possessions with which our technology and economy have endowed us. One of the books that announced the new way of economic thinking was entitled just that: *Modern Economic Growth*, by Simon Kuznets.[2] Few of us want to stop where we now stand, to freeze our collection of technical marvels. We expect economic production to continue increasing, without any gap or interruption, at some positive rate each year. Our children and our grandchildren will be richer than we are; if they are more numerous so that there are more problems of accommodating them, they will also have more powerful instruments for rearranging their environment.

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[1] Gould, S.J., 1989, *Wonderful Life: The Burgess Shale and the Nature of History*, W.W. Norton, New York, NY, USA.

[2] Kuznets, S., 1966, *Modern Economic Growth, Rate, Structure and Spread*, Yale University Press, New Haven, CT, USA.

Note that this outlook did not similarly dominate 19th-century economics. For it, land set limits to expansion; beyond a certain point more people would be poorer people. Economics has gone from a 19th-century sense of limits to today's revisionism that frees the economy from most external constraints.

Biology has also changed since the 19th century, but in the opposite direction. A hundred years ago it believed that the whole history of the world was upwards, culminating in Victorian society, and mankind would continue along the upward path. This was most clearly expressed by Herbert Spencer. He could confidently assure his readers that

> Progress ... is not an accident, but a necessity .... It is a part of nature,[3]

and there could be absolutely no doubt about its continuing. That is the view that Gould and his colleagues reject.

To express the two tendencies in their starkest form, biology went from a 19th-century view of indefinite progress to a 20th-century awareness of contingency, and economics from a 19th-century sense of limits of land and other resources to a 20th-century perspective of ever-continuing growth.

What has all this to do with the differences in attitudes toward growth? A great deal. Biologists have present in their discipline and in their minds the vast changes in the ecosphere, often sudden and catastrophic, that have taken place over geological time; they cannot exclude the possibility that such events will occur in the future; the changes man is now making are of the kind that could trigger the next such event. No similar concepts exist within the discipline of economics. Joseph Schumpeter[4] suggested the possibility of sudden mutations, but such thinking is far from the center of today's economics.

Axis 2 Scholars Like the Subjects They Study

Scholars would not produce worthwhile results if they did not have some affection for the subjects of their study. Anthropologists like the peoples among whom they live in much discomfort, and taxonomists like the species they identify and classify. Paul and Anne Ehrlich put first among the four values of biodiversity that

[3]Spencer, H., 1850, *Social Statics*, Part i, Chapter 2.4.

[4]Schumpeter, J., 1934, *Theory of Economic Development*, Harvard University Press, Cambridge, MA, USA.

> the dominant species on earth, *Homo sapiens* has an ethical, stewardship responsibility towards humanity's only known living companions in the universe.[5]

Samuel Preston opposed such views in commenting on a statement of the President of the Environmental Fund:

> These modes of thought seem to come particularly easily to biologists and ecologists, who as a group are almost surely endowed with an above-average reverence for nature and are inclined to view man's intrusions as violations of a sanctified order.[6] [Reference 6, page 69.]

And we similarly read in an earlier NAS economic report that

> no single exhaustible resource is essential or irreplaceable; it is valued for its economic contribution, not for its own sake.[7] [Reference 7, page 86.]

Less often referred to is the fact that just as biologists like nature, so economists like economic growth. They regard as a predominating objective the ever-increasing production of commodities and services. Liking one's subject of study can lead to bias, whether in natural or in social science. There is symmetry on this, up to a certain point.

Unfortunately for my well-meaning effort to reconcile economics and biology, we seem on this to fall into the quicksand of values. Is growth of goods and services a more worthy object of affection than species? Do we want growth enough to risk irreversible damage to the ecosystem that is our ultimate support? How do we rate our own incomes against the incomes of our children and grandchildren? Note that in this we are valuing increments at the margin – the environment versus even higher incomes for those already rich, the environment versus a larger number of poor people beyond the 4 billion or so already here.

For economics, a social science, people's attitudes are central; for natural science the attitudes of subjects can be disregarded. If everyone thinks that a bank is insolvent, then that bank will surely have to close its doors, however

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[5] Ehrlich, P.R., and Ehrlich, A.H., 1992, The Value of Biodiversity, *Ambio* **21**(3):219–216.

[6] Preston, S.H., 1986, Are the Economic Consequences of Population Growth a Sound Basis for Population Policy? pp. 67–95 in J. Menken, ed., *World Population and US Policy: The Choices Ahead*, The American Assembly and W.W. Norton, New York, NY, USA.

[7] National Research Council, Working Group on Population Growth and Economic Development, Committee on Population, 1986, *Population Growth and Economic Development: Policy Questions*, National Academy Press, Washington, DC, USA.

sound its balance sheet may be. Sociologist Robert Merton[8] spoke of the "self-fulfilling prophecy" to describe the general case where a belief, whether true or not, brings itself into existence. Label boys potential criminals and that leads many to criminal behavior.

An exaggerated sense of limits of the environment, its incapacity to support more people, would add to other factors weakening confidence. And at this point economists are both scientific analysts of the economy and actors in it. If they are conscientious they feel a duty not to darken the prospect unless they are absolutely sure.

Axis 3 Economics Sees Indefinite Market-Driven Substitutability as a Result of Continued Scientific Discovery; Natural Scientists are Skeptical

Always near the center of economics, and especially stressed in recent years, is the concept of substitution. If some material becomes rare its price rises, less essential uses of it are abandoned, the search goes on for fresh sources, and science turns to finding more common materials that will serve the same purpose.

References to history that will support this are easily found. Again and again industrial advance threatened to come to a halt because of a shortage; propagators of gloom were invariably proven wrong. William Stanley Jevons[9] in the 19th century saw Britain's population unable to buy the imported food on which it fed itself as its coal stocks were exhausted, so that its manufacturing would come to a stop. Nothing of the kind has happened. From the evidence of the past it is argued that any likely future shortage will be met by substitution, in which scientists, impelled by the inducements of free markets, will come up with the needed technologies.

Natural scientists should be enormously flattered by this confidence reposed in them. It is they, after all, and no one else who can make the advances in fundamental knowledge on which the technology of substitution would be based, the technology that would permit 10 or 12 billion people to live prosperously on this same planet by the middle of the 21st century.

[8] Merton, R.K., 1936, The Unintended Consequences of Purposive Social Action, *American Sociological Review* 1:894–904.

[9] Jevons, W.S., 1909, *The Coal Question: An Enquiry Concerning the Progress of the Nations and the Probable Exhaustion of Our Coal Mines*, Macmillan, London, UK.

Yet scientists reject the compliment; they take a view whose mature expression is given by the joint statement of this Academy and the venerable and equally distinguished Royal Society of London, which between them include a high proportion of the world's most creative scientists. I will refresh your memory by citing just two sentences:

> If current predictions of population growth prove accurate and patterns of human activity on the planet remain unchanged, science and technology may not be able to prevent either irreversible degradation of the environment or continued poverty for much of the world .... [I]t is not prudent to rely on science alone to solve problems created by rapid population growth, wasteful resource consumption and harmful human practices.[10]

Harvey Brooks expresses a measured outlook, but also with qualifications. Science clearly helps adaptation of larger populations, and yet in the very course of doing so, it often creates new problems. He goes so far as to say:

> It is not clear – or at least not agreed on – which side of the adaptation equation science and technology should be weighed in on.[11]

I can only sum up this part by saying that science is apparently less trusted by those who practice it than by its admirers.

Axis 4 Economics Makes People the Exclusive Object of Terrestrial Action; Biology Takes Them as One Species Among Many in a Web of Life

Each species, whether on land or sea, whether bacterium or elephant or man, eats and is eaten, exists, and is totally dependent on a commensal balance with the species around it. If it changes its numbers, say by an exogenous fall in its death rate, the balance changes; insofar as it increases that will have consequences for the species on which it lives. No species can escape this predicament, certainly the mere fact that its central nervous system

[10] Sir Michael Atiyah, President of the Royal Society of London, and Frank Press, President of the US National Academy of Sciences, 1992, Population Growth, Resource Consumption and a Sustainable World, A Joint Statement by the Officers of the Royal Society of London and the US National Academy of Sciences.

[11] Brooks, H., 1992, Sustainability and Technology, p. 37 in N. Keyfitz, ed., *Science and Sustainability: Selected Papers on IIASA's 20th Anniversary*, International Institute for Applied Systems Analysis, Laxenburg, Austria.

includes a brain weighing 1.5 kg does not release it from the web of life. No clever technologies will enable it to modify the laws of nature in its favor.

Do we need to be concerned that some of our actions greatly increase the rate of species extinction? Not if the species are mere insects or bacteria of no positive value, say economists. But a biologist, Robert Sokal, expresses a different view:

> [A]nother reason biologists value species diversity is that each species is the result of a unique, nonrepeatable evolutionary process. Nature has made several million experiments (the species) that have survived the process of evolution .... Whatever we destroy now is unrecoverable. It is as though some percentage of all the authors that have ever written were to be expunged from the libraries of the world.[12]

And Peter Raven and Edward Wilson insist that

> Wild species ... provide essential services to the ecosystem, from the maintenance of hydrologic cycles to the nitrification of soils.[13]

Kenneth Arrow[14] has been virtually alone among economists in giving systematic thought to this matter and developing an ingenious model for judging policy whose results may be irreversible.

Species are disappearing anyhow, so what matter if humans cause a few more to vanish? But it is not a matter of a few. All biologists who have written on biodiversity agree that the rate of loss through deforestation is far greater than the background rate before people came on the scene.

Both ecologists and economists say we should not take action to interfere with what is now going on. Unfortunately that verbal agreement translates into two diametrically opposed policy conclusions, depending on what one means by "interfere." For ecologists the present growth of population and goods is the grossest form of interference, and we should act to bring it under control if not to a stop at the earliest possible moment. For economists, we should hesitate to do anything that would interfere with the growth that is so necessary to employment and progress.

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[12] Sokal, R.R., Personal Communication, 15 April 1993.

[13] Raven, P.H., and Wilson, E.O., 1992, A Fifty-year Plan for Biodiversity Surveys, *Science* **258**(November 13):1099–1100.

[14] Arrow, K.J., and Fisher, A.C., 1974, Environmental Preservation, Uncertainty and Irreversibility, *Quarterly Journal of Economics* **88**(2):312–319, May 7, No. 351.

Axis 5 Economics Measures the Economy in a Time Scale of Years or Decades, Far Short of the Millennia and Eons of Biology's Evolutionary Time Scale

With their small numbers and their simple and stable techniques for gaining a livelihood, our hunting ancestors who emerged 1 or 2 million years ago did not greatly disturb the natural environment in which they lived. Lee and Devore say of human existence before the Neolithic,

> The hunting way of life has been the most successful and persistent adaptation man has ever achieved.[15]

The adaptation was based on a very long experience – people have lived by hunting 100 times as long as they have lived by agriculture, and several thousand times as long as they have lived by industry.

But what those hunting cultures could not adapt to was the agricultural world of increasing populations and expanding economies. Yet for Lee and Devore the matter of adaptation is not settled: the books are not yet closed. In their words,

> It is still an open question whether man will be able to survive the exceedingly complex and unstable ecological conditions he has created for himself.[16]

I cite Lee and Devore only to give the flavor of the long-range preoccupation of a discipline – anthropology – that straddles biological and social science.

It is not necessary to quote the other side to convince you that economics considers shorter periods and that it does not see the hunting and gathering cultures as an option. The business pages of the daily papers report today's market levels compared with those of last week; if they forecast, it is for conditions next month or later this year. Even Lawrence Klein's LINK model, which he recently extended to endogenize demographic variables, shows them only to the year 2025 – i.e., a little over 30 years.[17]

The contrast is expressible in terms of discount rates. With market rates the condition 30 years from now, let alone that on an ecological time scale, is of little importance. That businessmen making their decisions necessarily

[15] Lee, R.B., and Devore, I., eds., 1968, *Man the Hunter*, Aldine, Chicago, IL, USA.

[16] *Ibid.*

[17] Klein, L.R., 1992, A Linear Model for Environment and Development, pp. 213–242 in N. Keyfitz, ed., *Science and Sustainability: Selected Papers on IIASA's 20th Anniversary*, International Institute for Applied Systems Analysis, Laxenburg, Austria.

calculate with the rates that the bank charges them for loans means that they cannot afford to consider conditions even a generation or two down the line.

Axis 6 Economics is Concerned with Allocation Within the Economy, Biology with Absolute Size in Relation to the Biosphere

Herman Daly has been vocal in asserting that economics can study allocation of inputs and outputs of the economy indefinitely without ever discovering limits set by the ecosystem within which the economy has to sit. In his words neoclassical economic theory

> suffers from a total failure to distinguish the problem of optimal allocation of resources from the problem of the optimum scale of the economy relative to the ecosystem in which the economy is physically embedded.[18] [Reference 18, page 1719.]

While this is true of contemporary economics, it does not apply to the classics. We think back to the three classical factors of production – land, labor, and capital – that until this generation were the three equally emphasized inputs. With these an increase of population (i.e., labor), in the presence of the same land and capital, inevitably implied a fall in production per person. But today land and capital in the classical sense have mostly disappeared from production models. This reflects confidence that more food can be produced on the same land and that other shortages of resources will similarly be met by science, a confidence on the part of nonscientists referred to above.

Scale – just how big population and other elements of the economy are in relation to the size of the planet and its components – is the essence of the environmental problem, whereas allocation – which individuals and groups get what – affects the environment less. So why does economics neglect scale when it is so obviously relevant to all of its work, and not only environment? It does so, explains Kelley,

[18] Kelley, A.C., 1988, Economic Consequences of Population Change in the Third World, *Journal of Economic Literature* **26**(4):1684–1728, from Daly, H.E., 1986, Review of *Population Growth and Economic Development: Policy Questions*, *Population and Development Review* **12**(3):582–585.

> because useful estimates of scale effects are unavailable [and] substantial difficulties are encountered in assigning a value to the environment for future generations.[19]

Axis 7 Economics Deals with a Truncated Part of the Commodity Cycle, Ecology Aims at the Whole

The study of connections and consequences has been the main contribution of the popular ecological movement. It has drawn attention to the commodity cycle, which is much longer for ecology than for economics. For the economist the motor car starts with the exploration that discovers the iron ore and ends once the car leaves the showroom. The oil cycle similarly ends once the gasoline is pumped at the service station. Anything that happens before the oil is discovered by Caltex or after it is pumped into the customer's gas tank is of no consequence for the gross national product. Houses are the only item that is followed beyond the moment of sale to the consumer; nothing else is regarded as having any further relation to the market. Commodities become invisible and indeed nonexistent once they leave the market.

Thus the commodity history reported in accounting records is a truncated part of the whole. For the ecologist the oil cycle starts 100 million years earlier, with giant ferns decaying into the ground, and continues through the time when emissions are released as the car is driven, through to the effect of the nitrogen compounds on forests and the effect of the carbon dioxide on the global temperature. The automobile cycle does not end when the car is sold, but continues through the use of the car on the paved roads that it requires, its scrapping, perhaps its persistence on the landscape for many years, finally its disposal as landfill that integrates it with the ground again, but in very different form from the iron ore and other raw material components with which it started.

As Ronald Lee has pointed out to me,[20] the reason for this is that private individuals have no reason to trace goods through the time before they come onto the market or after they have passed out of it. This has consequences: the lack of information makes the entities invisible; proper records for a longer interval of the commodity cycle would draw needed attention to ecological effects. Unfortunately I have no better idea than anyone else on how such a record can be made.

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[19] *Ibid.*

[20] Personal Communication, 16 April 1993.

What has the length of the commodity cycle to do with population? A great deal; if the commodity cycle does not end the moment the consumer takes possession of the commodity, then the number of people who buy it, use it, and ultimately discard it will be decisive for the environment.

Working with the longer commodity cycle reveals another feature of our industrial life, the previously unsuspected connectedness of things. It was Barry Commoner,[21] more than 20 years ago, who had the revealing insight on this and urged us to trace through the way that everything we did affected everything else.

This connectedness of things is covered in economics, which places a condition on the market's operating to the social advantage: people must be charged the full costs of their decisions – including the smoke that harms the neighbors' lungs and the destruction of landscapes that will affect their children. The one admitted role of government is to ensure through taxes that such externalities are included in costs, which is to say that they are internalized. When that is done there will then be nothing to fear from more goods and more people. This and many other aspects are thoroughly covered in Robert and Nancy Dorfman's[22] collection, which provides the best instruction so far to be had on how to think about the economics of the environment.

Ecologists agree, but with a strong qualification. In the play of interests that constitutes democratic politics, how can such fine tuning of prices emerge? They are surprised that economists, who assert most vigorously the incompetence of governments, insisting in most contexts that decisions should be left to the market, argue for entrusting governments with this supremely delicate task of ensuring that all costs are internalized. If everything is connected with everything else it is difficult enough to calculate the right (shadow) prices, let alone to expect them to be implemented through the play of democratic politics.

Internalization of externalities is especially difficult in regard to childbearing. If the cost of children is only partly paid by their parents, and part of the cost for education and other services is borne by the community, then economic theory tells us that there will be more children than there would be if all costs were covered by parents. Here is one matter in which legislatures will never internalize costs. No one, whether parent or bachelor,

[21] Commoner, B.H., 1971, *The Closing Circle: Nature, Man, and Technology*, Alfred A. Knopf, New York, NY, USA.

[22] Dorfman, R., and Dorfman, N., eds., 1992, *Economics of the Environment: Selected Readings*, 2nd edition, Norton, New York, NY, USA.

Table 1. Performance characteristics of four eras.[24]

Era	Annual compound growth rates, %	
	Population	Per capita GDP
500–1500	0.1	0.0
1500–1700	0.2	0.1
1700–1820	0.4	0.2
1820–1980	0.9	1.6

The sample includes 16 countries, 12 from Europe, plus Australia, Canada, Japan, and the United States. GDP denotes gross domestic product.

would today vote for making education optional and putting its whole cost on parents; once the child is born he or she has to be educated at least up to literacy, to be able to hold a job and be a responsible citizen.

Axis 8 Both Disciplines Are Empirical, but the Data Are Not Totally Convincing

Both biology and economics are empirical sciences, and they have assembled voluminous evidence on the effect of population. But none of it is conclusive. Take one item from the extensive and careful researches of Simon Kuznets.[23] He was impressed by the fact that industrialization got under way at exactly the same time as world population began to accelerate. A recent set of estimates, over the past millennium and a half, for 16 countries now industrialized, can indicate the kind of data used by Kuznets (*Table 1*).

It will be seen that as the rate of increase of the population grew, so did that of the per capita gross domestic product. The 19th and 20th centuries are the first time in world history that such a phenomenal growth of population has ever occurred, and certainly the first time for industrialization and its accompanying rise of income. When over the course of thousands of years two events occur within a few decades of one another they must surely be related. The sense of a relation is strengthened when we note that the fall of the birth rate during the 1920s and 1930s was accompanied by the fall in income of the 1930s and that the subsequent rise of births after World War II was accompanied by a rise in income.

[23] Kuznets, S., 1973, *Population, Capital and Growth*, Norton, New York, NY, USA.

[24] Maddison, A., 1982, *Phases of Capitalist Development*, Table 1.2, p. 6, Oxford University Press, New York, NY, USA.

But given the virtual simultaneity of the changes in population and income, it is not clear which caused which. Does population drive the economy, which Kuznets and others have thought a possibility, or does the improving economy lead to fewer deaths, and hence to rising population?

Coale and Hoover[25] worked with projections. They made forecasts for India and Mexico assuming (a) more people and (b) fewer people, with other features the same in both forecasts. Substantially faster growth appeared with the smaller population assumption, largely because in it capital would increase more rapidly. For many years this view was widely accepted, but has now gone out of fashion.

Beyond this is a considerable literature using cross-national correlations. Are the countries with more rapidly increasing populations showing less increase of income? They are not. But interpretation of this fact is difficult. Ronald Lee gives his evaluation of this literature:

> [T]hese cross-national studies have not provided what we might hope for: a rough and stylized depiction of the consequences of rapid population growth; unless, indeed, the absence of significant results is itself the result.[26]

Kelley agrees:

> [S]tatistical correlations provide little prima facie information about the size or nature of the net impact of population growth on economic growth.[27]

And Simon Kuznets:

> [W]e have not tested, or even approximated, empirical coefficients with which to weight the various positive and negative aspects of population growth.[28] [Reference 28, page 339.]

Biologists do not mainly employ statistical data; for them no general law need be sought to prove the harm of population increasing beyond the

[25]Coale, A.J., and Hoover, E.M., 1958, *Population Growth and Economic Development in Low-Income Countries*, p. 328, Princeton University Press, Princeton, NJ, USA.

[26]Lee, R.D., 1983, Economic Consequences of Population Size, Structure and Growth, *Newsletter* **17**:43–59.

[27]See reference 18.

[28]Kuznets, S., 1960, Population Change and Aggregate Output, in *Demographic and Economic Change in Developed Countries*, A Conference of the Universities-National Bureau Committee for Economic Research, Princeton University Press, Princeton, NJ, USA.

high densities now existing. Special cases abound. I will mention only one, taken from the researches of historian Ping-ti Ho.[29]

The population of China has through most of history shown a slow rise to its present level of 1.1 billion, but there were two occasions on which it doubled within a few decades. One was in the 11th century AD and the other was in the 18th century. Ho found for the doubling in the 18th century that Portuguese sailors introduced various American crops into China, including peanuts, potatoes, and particularly corn. No longer was agriculture confined to river deltas and plains, where the irrigation needed for rice was possible, but hillsides could be easily cultivated. The direction of causation in this case is clear – the population built up to what the new crops made possible, a simple Malthusian effect.

Evidence and Proof in the Two Disciplines

The nearest I have seen to a general statement in biological writings is a proportionality model – with twice as many people there will be twice as many of all kinds of harmful effects as well as of good effects (writings of William C. Clark, Barry Commoner, Paul Ehrlich, Norman Myers, Léon Tabah, and others).

Economics points out that such an identity, which can never be wrong, can also never prove anything, and it seeks more sophisticated general laws. It does not accept that if population doubles everything else increases in proportion. Suppose that the doubling of population had some indirect good effects that could offset the harm of doubling. Ester Boserup[30] describes situations where population pressure forced private ownership and economic growth followed that provided for the increased population and also protected the environment. Such matters have to be looked at before the economist will grant that doubling population doubles the difficulties, or even increases them at all.

Thus we have from the economics side plentiful statistical data but they are not quite suited to proving a general law; on the side of biology are particular cases from which the induction of a general law is necessarily uncertain.

[29] Ho, Ping-ti, 1960, *Studies on the Population of China, 1368–1953*, Harvard University Press, Cambridge, MA, USA.

[30] Boserup, E., 1981, *Population and Technological Change*, University of Chicago Press, Chicago, IL, USA.

How Far Do the Eight Axes Help Us to Understand the Differences Between the Biological and Economic Stands on Population and Environment?

To remind you of what I have said, my eight axes are as follows.

1. Economics deals with growth, steady progress as against biological contingency. Hence biologists are better prepared to consider catastrophes resulting from human action.
2. Scholars like the subjects they study and seek the well-being of their subjects. Are more consumer goods preferable to the sparing of trees and species? Here reason fails and we fall into the quicksand of values.
3. Economics sees indefinite, market-driven substitutability as a result of scientific discovery; natural scientists, who make the substitutions possible, are skeptical. Should natural scientists have more confidence in their own abilities?
4. Economics makes people the exclusive object of terrestrial action; biology takes them as one species among many in a web of life. Can one species detach itself from the totality of life on the planet and act entirely on its own initiative?
5. Economic action is on a time scale of years or decades, far short of the millennia and eons of biology's evolutionary time. For the very short term, population and economic growth make little difference to the environment.
6. Economics cares little about scale, but is concerned with proportions and their allocation, whereas biology deals with absolute size in relation to the biosphere. The point is made by Herman Daly; Allen Kelley answers that data to incorporate scale are lacking. So far we have no way of measuring the capacity of the biosphere.
7. Economics deals with a truncated part of the commodity cycle, ecology aims at the whole. If goods disappeared into thin air at the moment of sale, the planet could stand far more of them.
8. Both disciplines are empirical, but the data are not wholly convincing. No one knows what kind of data will decide the question to the satisfaction of both sides.

It would be impertinent for me, a professional in neither field, to inform economists and biologists on their disciplines. That is not what I have tried to do. My effort has been rather to say how these two disciplines look from

the outside and, still from the outside, which of their features account for the different stands they take on population.

I do not interpret the differences between them as errors but speak rather of different problem formulations, arising out of the different ways that the disciplines serve the cause of knowledge and the welfare of society.

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