Human numbers, environment, sustainability, and health

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The complex relationships between economic development, population size, environmental conditions, and health have long stimulated discussion. Usually, however, health has not been regarded as the primary outcome of interest. For example, a prominent paper published in 1967, entitled "Health, population and economic development," examined various interrelationships between these three variables—with the exception of how population growth or economic development affected health.[1] Similarly, the much quoted report of the World Commission on Environment and Development of 1987 paid little attention to how environmental and economic changes affect population health.[2]

There is need for a more critical assessment of the ecological conditions under which health gains might be both generalised to the whole human population and sustained into the future.

Summary points

The rapid increase in population which began about two centuries ago has slowed since the 1960s, and stabilisation at around 10-11 billion is now expected

The disruption of natural systems on a global scale now seems a more serious potential harm from excessive numbers than does the occurrence of local difficulties in subsistence

The prospect of further intensification of ecologically disruptive economic activity means that paths to sustainability will require a shared radical "greening" of productive technologies and consumption habits

The main practical need, in the short term, is for indicators of ecological and social sustainability

There will be substantial scope for improving population health at any level of national income, by developing social and human, rather than material, resources

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Methods

We have familiarity with the scientific literature on population biology, the history of human ecology, and global environmental change and its potential health consequences. We consulted mainstream authoritative texts on these topics. The extensive literature on climate change was accessed through publications of the Intergovernmental Panel on Climate Change. Demographic, economic, and other characteristics for national populations are taken from publications of international agencies such as the World Bank and from the World Resources Institute.

The prehistory of human expansion

Most animal populations live off the sustained natural income (energy, nutrients, and water) of a single local environment. Population size is constrained by the "carrying capacity" of the environment. However, since their hunter-gatherer origins humans have been mobile "patch disturbers,"[3] depleting one patch and moving on to another. Furthermore, during the worldwide human dispersions many large animal species were apparently hunted to extinction.[4]

The eventual domestication of food species increased food yields and hence local carrying capacity. The emergence of agriculture led to a substantial increase in fertility: from four or five births per completed reproductive lifetime, as reported for traditional hunter-gatherers[5] (and, coincidentally, for free living great apes[6 7]), to five to seven births per reproductive lifetime.[8] As agrarian populations increased in size and density they altered, and often seriously degraded, local environments.[4] Dependence on starchy staples reduced nutrient quality, causing endemic deficiency diseases and malnutrition; famines were frequent.[9] Enlarged settlements nurtured the emergence of new infectious diseases,[10] thereby limiting the demographic impact of the increased fertility.

Thus premodern agriculture, while potentiating civilisation, probably also led to the lowest health levels yet experienced.[11] In India around 1900, for example, life expectancy was 20-25 years,[12] with half dying by age 10. Mortality risks in early life were 2-3 times higher than in today's least advantaged countries (which have life expectancies in the low 40s[13])—illustrating the large reductions in mortality that have occurred in low and middle income countries this century.

The exponential tendency

Wherever each individual can produce, on average, more than one reproducing offspring, the capacity for

website extra

An extra table appears on the BMJ's website

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exponential population growth exists. Hence Malthus's dark view of the human prospect: he argued that visions of human betterment, fostered by the French Revolution, would fail unless "preventive checks" such as late marriage and abstinence prevented the emiserating effects of overpopulation.

In nature, the tendency of animal populations to exponential growth is generally constrained by predation, by limited food supplies, by attrition due to infectious diseases, and by changes in reproductive behaviour that depend on density.[14] As numbers increase, one of the following patterns operates:

- Logistic growth, responding to immediate negative feedback, as carrying capacity is approached
- Domed or capped growth, responding to deferred negative feedback but necessitating a period of excess mortality
- Irruptive growth, with a chaotic post-crash pattern.[15 16]

On long timescales the most striking feature of human population growth has been the exponential increase over the past 200 years. Annual rates of increase actually peaked, at just over 2%, in the late 1960s[17]; the absolute annual increases peaked, at around 87 million, in the late 1980s and have since fallen to around 81 million.[13] The human population now seems to be in transition towards a stationary (non-increasing) population size 70-90% greater than today's population.[18]

A smooth transition to a stationary population size cannot be assumed, however, and it is the desire to avoid overshoot and collapse (the latter patterns above) that drives the search for "environmentally sustainable development." Simplifying, there are two main adverse outcomes to which excess human numbers might contribute: recurrent subsistence crises on a subnational or national level, and "planetary overload." Less simply, the second outcome would become manifest unevenly, with vulnerable local populations being first affected (by such things as depletion of freshwater supplies or climatic impairment of agricultural yields).

Local subsistence crises

Local crises in subsistence occur when numbers increase beyond the carrying capacity of the local environment, especially the cropland and water needed for food production. Undernutrition forces death rates up towards equilibrium with high fertility. Emiseration prevents economic development, leaving such populations "demographically entrapped."[19 20]

So far, developments in this direction have not generally been seen. The famines in recent decades (the most serious being the Chinese famine of 1959-61 with around 15-20 million deaths[21]) have been less associated with a decline in food producing resources per person than with economic mismanagement, as in the Chinese "great leap forward," or with warfare, as in parts of Africa. To what extent some such local conflicts reflect underlying subsistence pressures is difficult to assess.

"Planetary overload"

A major consequence of the increasing scale of human productive endeavours is the advent of global environmental changes. Population size and the material intensity of our economies are now so great that, at the global level, we are disrupting some of the biosphere's life support systems.[22] Those systems provide the natural processes of stabilisation, replenishment, organic production, cleansing, and recycling that our predecessors were able to take for granted in a less populated, less disrupted world.[23]

We no longer live in such a world. We are changing the gaseous composition of the atmosphere; there is a net loss of productive soils on all continents; we have overfished most ocean fisheries; we have severely depleted many great aquifers on which irrigated agriculture depends; and we are extinguishing at an unprecedented overall rate whole species and many local populations.[15 22 24 25] These changes to Earth's basic life supporting processes pose long term, and somewhat unfamiliar, risks to human health.[22 26] Meanwhile, the accompanying increases in local environmental pollutant levels, especially urban air pollution, exacerbate more familiar risks to health.

Contribution of population increase

Other things being equal, human disruption of the biosphere will be proportional to human numbers. But the potential multiplier from forseeable population increase (assuming 1.8 as a central estimate) is smaller than the potential multiplier due to global economic development—assuming no radical changes in technology. An increase in mean global incomes (currently about \$5000/person/year) to the current level of rich countries (currently about \$25 000/person/year) would multiply global economic product five times. The economic development scenarios being used by the UN's Intergovernmental Panel on Climate Change to forecast global emissions of carbon dioxide entail twofold to fivefold increases in global average income during the coming century.[27]

The debate on climate change illustrates well the relative effects of population and consumption levels. During the 20th century, the rate of fossil fuel emissions of carbon dioxide increased 12-fold while population size and carbon emissions each increased by around 3.5-fold (fig 1).[28 29] Population growth between 1985 and 2100 will contribute an estimated 35% of the increase in emissions; economic development will account for the remaining 65%.[30] To limit the carbon dioxide buildup to a doubling of its pre-industrial concentration—from 275 ppm to 550 ppm, a level that climatologists think may be tolerable—with a medium projection population of 9 billion by 2050, carbon dioxide emissions per person would need to be reduced by about two thirds from today's level.[31] To achieve a more desirable 450 ppm, reductions of 75-80% would be needed.

The scale of current effects

The absolute quantities of materials used, and wastes generated, by rich countries bears on the generalisability of their productive systems. Citizens of Germany, Japan, the Netherlands, and the United States consume 45-85 metric tons of materials per year. Most of the environmental impact is hidden from conventional accounting—for example, mine tailings, soil erosion, and greenhouse gas emissions—and much of it occurs offshore. "More than 70 percent of the materials that flow through the Dutch economy . . . never touch Dutch soil."[13] In other words, economic activities in high income countries already incur substantial environmental and ecological deficits.[32]

Overall, then, the larger potential threat is not from the increase in human numbers in itself but from today's globally averaged, mildly environmentally disruptive humans becoming highly disruptive[33]—that is, from attempts to generalise production and consumption patterns typical of today's rich countries. Recent attempts at "full cost accounting" estimate that the demands of the current world population exceed global carrying capacity by approximately a third.[32]

Increases in "income" (broadly construed as opportunity) among the world's poor majority are an essential goal. Therefore it is likely that equitable paths to sustainability will require substantial reductions in ecological disruption per unit of income—that is, a radical "greening" of productive technologies and consumption habits. Because rich countries remain the main source of new knowledge and new technologies, responsibility for finding paths to sustainability rests mainly with them. Minimising the probabilities of long term harm to population health is therefore central to the population debate.

Guides to sustainability

The probabilities of specific long term harm to health from adverse effects of economic development will remain uncertain in the short to medium term. More relevant to current policy choices is the development of indicators of material progress that show if we are moving closer to, or further away from, sustainable paths of economic development.

The "living planet index"

The "living planet index" is one of the first systematic attempts to quantify the effects of human activity on natural ecosystems.[34] It gives equal weight to three contributing indices: forest ecosystems (area of natural forest cover) and freshwater ecosystems and marine ecosystems (trends in the populations of 70 and 87 indicator species, respectively). Set to 100 in 1970, it was estimated to have fallen to 68 by 1995—an unsustainable rate of decline (fig 2).

Green accounting

Sustainability can be better operationalised using measures of economic "stock" (capital, including natural capital and human resources) than using measures of "flow" (income). Conventional national income accounts are biased in treating depletions of natural capital as income and are insensitive since they provide little indication of legacies to future generations. The World Bank has noted that if "sustainable development is about leaving future generations more capital per capita than we have had, then the rate of genuine saving [conventional savings plus education spending minus natural resource depletion and pollution damage] becomes a good measure of whether our aggregate activities are on a sustainable path."[35]

A shift of emphasis from income flows to stocks of wealth, especially stocks of human resources, clarifies the scope for enhancing health at any given level of income—important if we are to maximise human wellbeing while minimising flows of materials and energy.

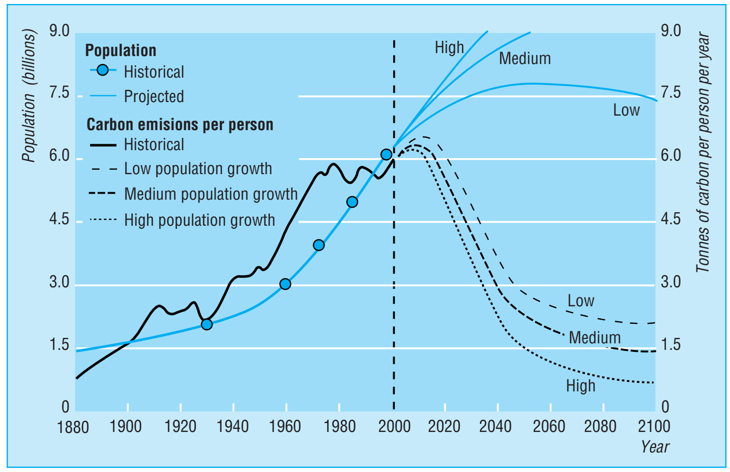

Fig 1 Historical and projected carbon emissions per person, and projections of allowable emissions per person at high, medium, and low projections of population growth to limit atmospheric carbon dioxide concentrations to 450 ppm

Economy and health in a green light

In all but the very poorest populations, human and social resources determine mortality levels more than does income. For example, among countries with per capita incomes in the range of $2000-5000 in 1995, lower child mortality was associated with better population coverage by public health and essential clinical services (indicating both the responsiveness of the state to the needs of the less well off and the effectiveness of public administration[36]—that is, elements of "social capital"), higher school attendance rates for girls, and more radios and television sets (indicating enhanced capacities to make use of knowledge from the outside world). Child mortality was over three times higher in the five worst performing countries than in the five best (see table on website).

The greater dependence of health on "stocks" of human resources than "flows" of income is also shown by the surprising capacity of many low and middle income countries to achieve mortality declines even in the face of stagnating or declining income levels. For example, child mortality in the countries of Central America has declined by a median annual rate of 5.5% since 1980 despite there having been little improvement in incomes. This was much faster than in the preceding 20 years, when incomes rose strongly.[13]

For rich countries, health manifestly depends less on the consumption opportunities provided by

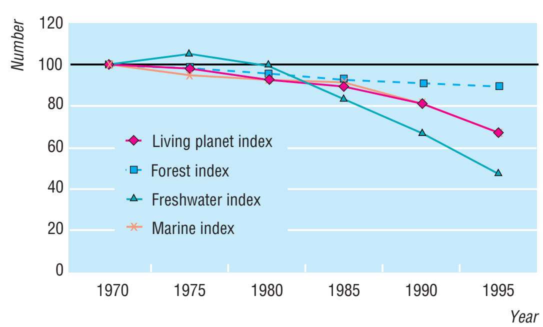

Fig 2 The three contributing indices of the living planet index were set to 100 for 1970

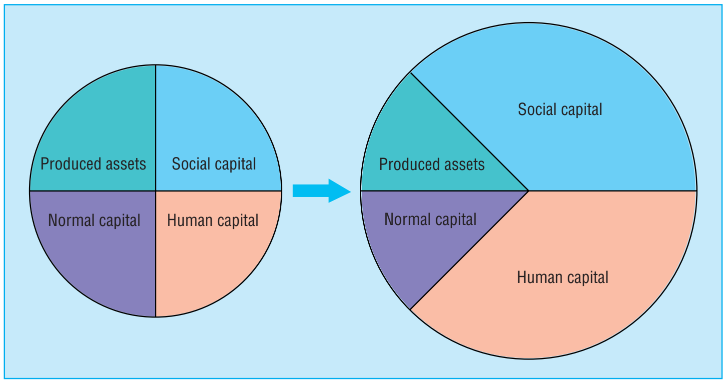

Fig 3 Sustainable development with changing proportions of different kinds of wealth per person[35]

income than on personal and social capacities to protect and enhance health. These capacities reflect, at the individual level, determinants such as schooling and, at the social level, determinants such as food cultures (whence the protection against cardiovascular mortality in Mediterranean countries[37]) or drinking cultures (whence the catastrophic mortality increase in Russia during its economic and political transition,[38] in contrast, for example, to Georgia or Armenia, despite even greater falls in income[13]).

By appreciating that wealth resides in stocks of various types of capital, rich countries can envisage a pattern of development which, by augmenting human and social capital while protecting natural capital, should better protect and enhance health (fig 3). By contrast, concentrating on increasing income is unlikely to enhance health (mortality is only weakly related to income among middle and high income countries[13])—quite apart from its ecological unsustainability.

Conclusion

As the world becomes increasingly interconnected economically, politically, physically, culturally, and electronically, the discourse about population-environment-health relationships and about sustainability is shifting from local to global contexts. In an interconnected world, local subsistence crises may more readily (although not certainly) be averted by external subsidy. Meanwhile, no such external subsidy is available in relation to the world at large. Without radical changes towards less ecologically disruptive economies, a larger population in future will not be sustainable. Such a change requires our understanding of the fundamental dependence of humankind on the ecosphere, and our recognition that we face a global "common property" problem soluble only through unusual cooperative action across traditional divisive and competitive barriers.[39]

As guides to sustainability, changes in stocks—whether of natural ecosystems or of all kinds of wealth, including natural capital—currently offer the most promise. Meanwhile, in all but the poorest countries, there is substantial scope for enhancing health at any given level of income (and its associated environmental pressure) by the development of social and human resources.

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