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Since the publication of The Brundtland Report, the UN, the World Bank and most nations have advocated sustainability as a goal. However, the world is currently being run in unsustainable ways, so we must explore the implications of creating a sustainable world.

The Global Ecosystem and the Economic Subsystem

One measure of the size of the human economic subsystem relative to the total global ecosystem of which it is a part is the level of throughput of resources from the ecosystem to the economic subsystem. This level can be measured by the product of population times per capita resource consumption. The global ecosystem is the source of all material inputs, as well as the sink for the wastes of the economic subsystem, and it has limited regenerative and assimilative capacities. Since the size of the human economic subsystem relative to the total global system is very large today, the limited capacity of the global system to support the economic subsystem is being stretched. It is important to ensure that the human economy be limited so that the ecosystem can support it. This will require throughput reduction.

Localized Limits to Global Limits

Human economic activity and the resulting pollution have reached all parts of the world. The current constraints on economic activity are due to the sink limits of the global system. The key limit is the sink constraint on absorption of wastes produced by fossil fuel use. There are a number of signs that the limits have been reached. Five of them are discussed below.

1) **Human Biomass Appropriation:** As calculated by Vitousek et al.,[1] the human economy uses about 40% of the net primary product of terrestrial photosynthesis today. Thus, with one doubling of the world's population we will be using 80% of the net primary product of terrestrial photosynthesis, and shortly thereafter 100%. This scenario is ecologically impossible and socially undesirable. The time has come to ask when we will be willing to say enough.

2) **Global Warming:** The second evidence that limits have been exceeded is global warming. Carbon dioxide accumulation is pervasive and it is expensive to cure. Furthermore, cropping patterns will be affected due to the resulting climatic changes. Significant changes in temperature have been recorded in the recent past. There is still uncertainty about whether global warming has actually started, but all evidence suggests that it may have. Neither the effects nor the required policy responses are yet clear.

The dominant cause of the accumulation of green house gases is the fossil fuel-based human economy. Other contributors to global warming are pollutants like methane, CFCs and nitrous

oxide. There is no price to polluters for using atmospheric sink capacity, although the real opportunity costs may be very high. The costs of rejecting the greenhouse hypothesis, if it is in fact true, are far greater than the costs of accepting the hypothesis even if it proves false. If nothing is done until irrefutable evidence comes in, the costs of the influx of millions of refugees from low-lying and coastal areas, of damage to ports and coastal cities, and of damage to agriculture will be exorbitant. Action is necessary, if for no other reason than to insure against these possibilities. Prudence should be paramount. As Amory Lovins has suggested, abating global warming may save, not cost, money.

To the extent that energy use reflects economic activity, carbon emissions are an index of the scale of the economy. Decoupling economic growth from energy throughput and increases in CO_2 seems achievable, as the recent experiences of Japan, the United States and Sweden attest. This can be accomplished by making a transition to renewable forms of energy, including biomass, solar and hydro.

3) **Ozone Shield Rupture:** The third evidence that limits have been reached is the rupture of the ozone shield. Two ozone holes have now been detected: one over Antarctica and another over the Arctic. The consequences of these ozone holes include increases in the incidence of cancer and many other diseases, as well as upsetting balances in natural vegetation. Even if CFC emissions cease today, it will take 100 to 150 years for pre-damage levels to return. The global nature of this problem is evidenced by the fact that while 85% of the CFCs are released in the North, the main hole appeared over Antarctica.

4) **Land Degradation:** Land degradation - i.e., "decreased productivity such as caused by accelerated soil erosion, salination, and desertification"(13) - is not new, though the scale of degradation has mushroomed. About 35% of the earth's land is now degraded. Soil loss rates range from 10 to 100 tons per hectare per year, seriously affecting the world food economy. In addition, the shortage and subsequent over-harvesting of fuel wood also lead to land degradation.

5) **Decrease in Biodiversity:** The increase in the size of the human economy has resulted in the extinction of species at the fastest rate in recorded history. The tropical forests are being destroyed at a rate of 168,000 square kilometers per year. While estimates of the number and rates of species extinction vary, they are all large. The destruction of the tropical forests increases poverty, and there is little beneficial trade-off with development.

Population

Reducing population growth in developing and developed countries is essential to achieve sustainability. Population control is needed in the developed countries, as they consume a large part of the world's resources and hence overpollute, and help must also be provided to the developing countries for family planning. Moreover, poverty in any country stimulates population growth, so direct poverty alleviation is essential. Developing country populations are increasing at a faster rate than their economies can provide for them. Even if energy consumption remains at its current inadequate levels in these countries, population growth will increase their commercial energy consumption 75% by the year 2025. To provide the resources

needed for poverty alleviation in developing countries, developed nations must shift from input growth to qualitative development.

Growth Versus Development

Given the size of the economic subsystem relative to the global system of which it is a part, as well as the strains on the regenerative and assimilative capacities of the global system, opinions differ as to how much the economy needs to continue to grow. While some authors, including Brundtland, call for continued growth, others believe that to achieve sustainability quantitative growth should stop and give way to qualitative development. According to Brundtland, some necessary conditions for sustainability include: production of more with less through conservation, technological improvements and recycling; reduction of the population explosion; redistribution from overconsumers to the poor; and - a point Brundtland was fuzzy on - the transition from input growth to qualitative development. Poor countries must be spared further hardship during the transition to sustainability. While Brundtland commendably advocates growth for poor countries, with respect to the resource consumption of different groups of human beings, sustainability will require both raising the bottom and lowering the top.

Conclusion

As economies move towards service-oriented growth from industrial growth, there is less damage done to the source and sink functions of the globe. The transition to sustainability will be assisted by technologies that are less throughput intensive. However, these changes will be insufficient, as the potential growth of the service sector relative to the production of goods has limits, and many services also have high throughput. In addition, "hi-tech" growth that is less throughput intensive may not be affordable in those places that need the most growth, i.e., developing countries. Part of the solution will be massive technology transfers from industrial to developing countries.

Notes

1. Vitousek, Peter M., et al., “Human Appropriation of the Products of Photosynthesis,” in *BioScience* 34 (6): 368-73 (1986).