On growth and the form of limits

The anniversary of a historic publication provides the chance to reflect on how we consider limits and on the value of cross-fertilization between research traditions.

The year 2022 is proving historic for many reasons, some lamentable and ongoing. Among those that make us reflect is the 50th anniversary of *The Limits to Growth*[1]. This book remains a powerful expression of the idea that economic growth can be limited by a range of interacting factors, including environmental ones. The authors, led by Donella Meadows, conducted something akin to an early integrated assessment model, a quantitative exploration of social and environmental processes and their interactions. As discussed in our November 2021 editorial[2], the dimensions included were human population, food production, pollution, industrialization and non-renewable-resource consumption. In the standard model run, food and industrial output per capita fell after resources fell and as pollution rose, while variables stabilized in one of the other scenarios. Effectively, this exploration suggested that socio-economic growth can not only be limited in different ways, but that the limits to growth can take different forms.

Perhaps understandably, *The Limits to Growth* had a polemical reception. Some considered it a groundbreaking recognition of what the famed Apollo image showed, that a finite Earth has only so much and that such biophysical constraints, among others, will necessarily limit socio-economic systems, including their growth. Others considered the argument heresy, suggesting the exercise was simplistic and that innovations, including around natural resources, will push back perceived limits.

Debate aside, the study and book's influence on sustainability science is clearly profound. The notions of planetary boundaries, ecological footprints and others owe much to the idea that socio-economic systems and environmental systems interact to produce behaviour that can be limiting. As well, it informed a range of sustainability-related work in fields from political ecology to Earth-system science.

The consideration of growth and limits is actually older and varied, though. Long before and still ongoing, biologists, physicists and others have considered relationships between growth, size and shape — effectively, between growth and limits. Early efforts focused on living organisms. Biologist D'Arcy Thompson's book *On Growth and Form*[3] considered how physics constrains the structure and growth of organisms and their parts, from cells to shells. This and other efforts helped to stimulate a renaissance focused on how a range of factors, including individual growth rates, vary with body size[4]. In turn, this work on biological scaling informed work on urban scaling[5,6], which considers how properties of cities scale with their size. Various factors, including resource constraints and the geometry of networks ferrying resources and wastes, limit growth in these scaling studies.

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Cross-fertilization between research on limits to growth and on scaling could bear useful fruit. Both traditions have enlarged our understanding of what it takes to support a complex entity full of life. The Earth may be the ultimate expression, making such studies incredibly challenging and easy to criticize. But not grappling productively with such complexity is coming at an increasingly dear price.

We must continue to think creatively about the relationships between growth, form and limits in modern socio-economies, including those linking most people and environments on Earth today. One thing studies suggest, when considered together, is that growth itself can be varied, and that organisms, cities, and economies can stretch, effectively, in different ways. In organisms, for example, and as Thompson observed, the bodies of some deep-sea fish species look like sheared versions of others. The morphology of cities can also appear as variations on common themes. A second implication is that these variations reflect constraints and opportunities. A third is that there are multiple potential constraints, from energy to disease to history itself, as when previous forms constrain future possibilities[7]. Organisms and cities are both complex systems with key similarities, but the seductiveness of the analogy must be balanced against realistic consideration of differences[8]. For socio-economies, themselves so complex, there should be many guides and, effectively, limits, and potentially many ways to 'grow'. The efforts to move beyond gross domestic product (GDP) are effectively explorations of alternative growth trajectories.

Scholars and society more broadly should think about what varieties of growth we can, in all senses, afford, and what constraints can, or will, guide us there. The global human experiment is always both old and young, rich if hobbled with history yet still crashing like a toddler into one new obstacle after another, testing its limits and with the ever-fresh wounds to prove it. ❐

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