# Pattern of growth

Controversy and disagreement over economic growth — its necessity, costs and potential limits — started several centuries ago. In the early 1800s, Thomas Malthus first suggested that the human species faced physical and biological constraints that would inevitably check its growth through famine and disease. When Malthus's fears didn't materialize, later economists drew confidence: perhaps human ingenuity and progress know no limits?

More recently, the 'Limits to Growth' movement — stimulated by a book of the same name published in 1972 by a think-tank known as the Club of Rome — took seriously the observation that economic growth has costs and consequences, especially in environmental degradation. Simple computer models were used to explore likely scenarios for future human development on Earth; results suggested that continued growth in a 'business as usual' scenario would likely end in socioeconomic collapse sometime in the twenty-first century. These concerns weren't so much shown to be wrong as ignored or shouted down by influential economists and business interests; a recent study revisited the book's predictions and found many of them to be more or less on target (G. Turner, *GAIA* **21,** 116–124; 2012)

To many economists, it seems, the idea of limits to growth breaks in an unacceptable way with central theoretical notions about the benefits of technological innovation and economic exchange. But discussions over the matter really do involve a collision of ideas and methods from the social and physical sciences, a collision of very different ways of thinking. If we're going to build a serious understanding of growth, its ultimate consequences and future, there has to emerge a science that is both social and physical at the same time.

Physicist Tom Murphy gives a highly amusing account of a chance conversation at a scientific meeting between himself and a prominent economist (http://go.nature.com/GvhWsc). Murphy raised the matter of limits to growth, pointing out that growth in energy use has held steady at around 2% yearly over the past three centuries. Exponential growth of this kind, if perpetuated, has rather obvious limits owing to thermodynamics alone. Talk all you want of future improvements in energy efficiency, but the energy we use always ends up as heat in the environment. With 2% yearly growth, this energy dissipation alone, Murphy argues, would be enough to boil the oceans in only four centuries.

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This is, of course, a reflection of just how violently fast exponential growth really is. That pattern simply cannot continue. From a fundamental perspective, we're going to ultimately have to limit our use of energy (barring fantastic visions such as escape to outer space).

But maybe, the economist countered, we can find a way to continue economic growth without using more energy, or at least without energy use growing as fast? We might find a way to use our energy more intelligently. In particular, we're clearly shifting our economic activities on a massive scale to be more information-intensive, with many goods and services linked only to the processing or production of information. Perhaps we might find ways to process information (reversible computation, for example) that would consume very little energy, and thereby uncouple economic growth from energy growth?

Murphy's recollection of the conversation ends with some questions hanging in the air, such as whether perpetual economic improvement might still be possible even with a fixed overall gross domestic product (GDP).

If so, it seems, this kind of 'growth' would be very different from what we know today, which is economic growth directly linked to energy growth. In an interesting study last year, biologist James Brown and others assembled global data on economic growth and energy use from the period 1980–2003 to scrutinize the link between the two. They found that across many nations, energy use doesn't seem to grow quite as fast as economic output; rather, there's an efficiency of scale that begins to kick in. Larger economies require more energy, certainly, but they use it somewhat more efficiently than smaller economies.

More specifically, they used data on energy use and GDP for 220 nations. The energy use included the metabolic consumption of the human population, as well as the energy of all sources used for industry, transport and so on. Plotted on a per capita basis, the data show a robust scaling relationship, with considerable variation between nations: generally, energy use increases in proportion to GDP raised to the power of 0.75 (it is slightly sub-linear). Some countries (Russia, Ukraine, China) were less energy efficient, whereas others (Congo, Hong Kong, Japan) were more efficient. Over time, all grew roughly along the same scaling path (J. Brown *et al., Bioscience* **61,** 19–26; 2011).

Curiously, this scaling pattern looks very much like that known in biology for the scaling of animal metabolic rate with body mass. Brown and colleagues suggest this may reflect the fact that economies really do have something closely akin to a metabolism, as they "consume, transfer and allocate energy" to maintain all the structures and processes on which economic function depends. The authors also looked at a host of measures related to the ecological footprint of various nations — total waste, electricity and aluminium produced; televisions per 1,000 people — and found, at least over the period considered, that no nation has managed to increase GDP without at the same time using more energy and natural resources, with attendant increasing environmental impact.

Hence, there seems to be a natural relationship between economic activity and energy used, at least as we have conceived and practised economic activity so far. More activity generally demands more energy use, and we do not yet have a counter example of any nation growing economically while using less energy. In this sense, the notion of the information economy that would become somehow detached from greater energy use remains more fantasy than reality.

Perhaps some fundamental transformation in our future technology will reduce the pattern described here to a historically contingent and only temporary relationship. Perhaps one day soon we will be able to grow economically and do more with less. But there's nothing to support that idea at the moment. To believe in unlimited growth right now still seems to be an act of pure faith. ❐

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