The Cosmic Macro-Economy

Herman Daly

Is there an economic structure or fact that governs our lives, but is so large and all-encompassing that it remains nearly invisible? Many of us have failed to see the overarching fact that all life and all wealth is maintained by an entropic flow of matter and energy through an economy that is a subsystem of a finite and non growing Earth. Consequently the scale of the economiic subsystem cannot exceed that of the total earth system. In other words physical growth of the economy is limited.

To be sure, we learn that we depend on the sun's life giving support as well as the photosynthesizing organisms who make it available to us. Yet we quickly forget, and are left to wonder what it is about sunlight that supports life, given that energy is neither created nor destroyed. And besides, doesn't life require matter as well as energy? Then we learn about entropy. Living and producing both require "sucking low entropy from the environment" as physicist Erwin Schrodinger aptly put it. Entropy is the qualitative difference between equal quantities of useful matter-energy and waste matter-energy. The difference between useful resources and useless waste seems a very basic fact for economics, but economists seldom learn about the laws of thermodynamics.

An exception was Nicholas Georgescu-Roegen whose magisterial book The Entropy Law and the Economic Process tried to correct this defect, but met with limited success in convincing his fellow economists. But if we look again at his work we can get a picture of the too-large-to-see cosmic structure that ultimately governs the maintenance of life and wealth. From Georgescu-Roegen we learn that there are two sources of the low-entropy flow that sustains our lives: the solar and the terrestrial. They differ significantly in their patterns of scarcity. The solar source is only energy, no materials, and is practically infinite in its stock dimension, but finite and dispersed in its flow rate of arrival to earth. The terrestrial source of low-entropy consists of both matter and energy - concentrated deposits of minerals in the earth's crust, including fossil fuels which are ancient solar energy accumulated over billions of years. Terrestrial low entropy is limited in its stock dimension, but can be used up at a flow rate of our own choosing. We cannot mine the sun to use tomorrow's solar energy today, we must wait for it to arrive tomorrow. We can, however, mine and use up today the accumulated solar energy of Paleolithic summers, and have chosen to use it rapidly, at least during the past two centuries. We have thereby become more dependent on the scarcer terrestrial source, rather than the abundant solar source, than we were in pre-industrial times. We prefer the terrestrial source because it is already here and already concentrated—and we are impatient to use it to grow. We, especially economists, think that thanks to growth the future will be richer than the present, and, therefore, the (growth-inflicted) costs of depletion and pollution will be easier to bear.

Solar energy is abundant and renewed every day. To capture its flow requires extended space covered by a "net" made out of highly structured materials. These structures wear out over time and need maintenance, as well as replacement, and of course require initial construction. These needs must be largely met out of our diminishing terrestrial stock of low-entropy matter-energy. Current sunlight and terrestrial material collectors are complementary factors. The one in short supply is therefore limiting. The limiting factor is terrestrial low-entropy, concentrated materials in the earth's crust, including fossil fuels. To see how useless abundant solar energy would be without material structures capable of capturing it, one need only look at the barren moon, Mars, etc.

The economic question then is, how best to use the limiting factor? We should focus our attention on how to allocate our scarce dowry of terrestrial low entropy. We have two general alternatives. We can consume it directly in building cruise ships, jetliners, rockets to Mars, and Cadillacs—or we can invest it in structures that tap into our more abundant solar source of low entropy. We collect solar energy in two basic ways. The first way is indirectly through the photosynthesis of plants in agriculture, forestry, ranching, hunting, fishing, etc. Other species concentrate, to our benefit, the solar energy captured in the process of photosynthesis. And we exploit their population growth, either by taking only a sustainable yield or by taking a greater than sustainable yield and thereby converting a renewable resource into a nonrenewable one. The other basic mode of capture is by investing in direct solar collection by modern technologies such as photovoltaics and concentrating solar-thermal power.

Our human lives require the conversion of incoming solar energy by photosynthesizing plants and thenceforth other species at lower trophic levels into food and fiber above their own maintenance requirements. Given sufficient bounty from these other species, sustainably exploited, we can then invest resources beyond our own mere maintenance. Investing terrestrial low entropy in a plow, for example, increases our ability to tap incoming sunlight for vital purposes. Spending it on a Cadillac, on the other hand, is not a vital purpose but rather a luxury expenditure of our limiting factor. This led Georgescu-Roegen to a rather dramatic conclusion: "The upshot is clear. Every time we produce a Cadillac, we irrevocably destroy an amount of low entropy that could otherwise be used for producing a plow or a spade. In other words, every time we produce a Cadillac, we do it at the cost of decreasing the number of human lives in the future."

It seems that in spending our limiting factor we face a tradeoff. Using it up on present luxury has the opportunity cost of fewer lives in the future . Saving it for future plows has the opportunity cost of less luxury in the present. This basic tradeoff exists regardless of how efficient the solar collectors may be.

Georgescu-Roegen's argument was anticipated by Henry David Thoreau's oft-quoted insight that "the cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run." Or as John Ruskin put it, "There is no wealth but life. Life, including all its powers of love, of joy, and of admiration. That country is the richest which nourishes the greatest [cumulative] number of noble and happy human beings." Life requires current sunlight, and the most vital use of accumulated Paleozoic sunlight is to build or preserve material structures capable of increasing our ability to capture current sunlight.

The realization that the cost of present luxury is foregone future lives is dramatic and sobering. However, life at a mere basic subsistence does not offer much enjoyment, and most people are certainly not willing to live that way. Yet extravagant luxury and gross inequality become less tolerable when the same reasonable people recognize the opportunity cost in terms of even "good life" foregone. So, we are forced to ponder a big question: should we not strive to maximize cumulative lives ever to be lived over time by depleting terrestrial low-entropy stocks at a flow rate that is low, but sufficient for a "good life"? There is no point in maximizing years lived in misery, so the qualification "sufficient for a good life" is important. And there remains the question of of how much life of other species is necessary for a good world.

Even with careful use, the scarce terrestrial stocks eventually will be gone, even as the sun continues to shine. Mankind will revert to what Georgescu-Roegen called "a berry-picking economy" until the sun burns out—if not driven to extinction sooner by some other event, as seems increasingly likely. But in the meantime, striving for a steady state with a rate of resource use sufficient for a good (not luxurious) life, and sustainable for a long (not infinite) future, seems to be a worthy goal. It's a goal of maximizing the cumulative life satisfaction possible under finite and depleting terrestrial resource constraints.

Does this cosmic invisible structure, once recognized, raise any questions for current practical economic policy? Consider:

- How much resource use per capita is sufficient for a good life?

- How do we ensure that everyone gets that amount?

- How large a population can a viable technology support at that standard of consumption?

- How much of the scarce terrestrial stock of low entropy can be economically invested in further tapping the abundant solar flow? In other words, which direct solar technologies actually have a positive net energy yield?

- Is indirect or direct collection of solar energy a more economic investment at the present margin (i.e., more reforestation and conservation of ecosystems, or more photovoltaic collectors and windmills?

- What is the best policy sequence---efficiency first to make frugality less necessary? Or frugality first to make efficiency more necessary?

These questions have not been central to modern growthist economics—indeed, not even peripheral! But a cosmic macro-economics puts them front and center.

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