"Summary of article by Nicholas Georgescu-Roegen: The Entropy Law and the Economic Problem" in Frontier Issues in Economic Thought, Volume 1: A Survey of Ecological Economics. Island Press: Washington DC, 1995. pp. 177-179

Social Science Library: Frontier Thinking in Sustainable Development and Human Well-being

"Summary of article by Nicholas Georgescu-Roegen: The Entropy Law and the Economic Problem"

The influence of a mechanistic approach on the founders of neoclassical economics can still be seen today in, for example, the representation of the economic process as a pendulum movement between production and consumption within a completely closed system. The mutual influences that the economic process and the material environment have on each other are not recognized by standard economics. Marxian economists also represent the economic process as a completely circular and self-sustaining system, and do not recognize the interrelations between the economic process and nature. However, the history of mankind unequivocally shows that nature plays an important role in the economic process. This paper considers the consequences of this role, and seeks to show that some of them are of utmost importance in understanding the linkages between nature and the evolution of man's economy.

Given the First Law of Thermodynamics - that matter and energy can neither be created nor destroyed - it is worth asking what the economic process actually does. When viewed from the purely physical perspective, the economic process continuously absorbs and throws out matter-energy. This is a partial process, circumscribed by a boundary across which matter and energy are exchanged with the rest of the material universe. Valuable natural resources enter the economic process, and valueless waste is thrown out. In thermodynamic terms, the economic process converts matter-energy from a state of low entropy to a state of high entropy.

What is entropy? The 1948 edition of Webster's Collegiate Dictionary defines entropy as "a measure of the unavailable energy in a thermodynamic system." Energy exists in two forms: available or free energy, and unavailable or bound energy. Man has almost complete command over free energy, but cannot use bound energy. For example, the chemical energy in a piece of coal is free energy, whereas the heat energy contained in the water of the seas is bound energy. Free energy implies the existence of ordered structure, while bound energy is energy dissipated in disorder. The Second Law of Thermodynamics, the entropy law, states that the amount of bound energy of a closed system continuously increases. Once a system has reached thermodynamic equilibrium (i.e., when all energy is bound), the only way to lower its entropy is to bring in free energy from outside the system. However, the decrease in entropy of the closed system can be obtained only at the cost of higher entropy elsewhere. When man converts copper ore (relatively higher in entropy) to copper metal (relatively lower in entropy) there is a more than compensating increase in the entropy of the surroundings. The lesson from thermodynamics is that, in entropic terms, the cost of any biological or economic enterprise is always greater than the product.

Why does the economic process go on? The purpose of the economic process is the enjoyment of life, but both the enjoyment of life and continued economic progress depend on the availability of environmental low entropy. Every object of economic value has a highly ordered structure. In fact, a number of historically important events have begun as searches for environmental low entropy. Thus it is apparent that the economic process is not an isolated, circular affair but a unidirectional, irrevocable evolution, tapping low entropy and inevitably producing high entropy, because it is anchored in a material base subject to definite constraints.

The Industrial Revolution saw economists beginning to ignore the natural environment when representing the economic process. The powers of science were exaggerated, and it was argued that there were no real obstacles to progress; constraints imposed by the material environment were not recognized. In fact, serious thought was given to the notion that it was possible to unbind bound energy. As a result, scientists and economists failed to realize that "better and bigger" products could not be made without "better and bigger" waste as a by-product. Even now some suggest that problems of pollution can be dealt with either by producing no waste, or by recycling wastes. While recycling can take place, the entropic cost of recycling is much greater than its entropic benefits.

Although the globe may be surrounded by free energy, either the costs of tapping it are too high to be worthwhile, or the technology does not exist. For example, the immense thermonuclear energy of the sun cannot be directly tapped as no material container exists that can resist the massive temperatures of the reactions. Two sources of free energy are accessible to man. The first, the energy from mined sources, is a stock, while the second, solar radiation intercepted by the earth, is a flow. There are three important differences between these two sources:

1) man has almost complete control over energy from terrestrial stocks, but has no control over the flow of solar radiation;

2) terrestrial sources provide low-entropy energy to manufacture our most important implements, whereas solar radiation, which is the source of chlorophyll photosynthesis, is the primary source of all life; and

3) the existing energy in terrestrial stocks is a small fraction of that contained in the sun.

In light of these differences, the population problem assumes a new dimension. There are differences of opinion about the effects of population growth and the world's ability to support increases in the short run, but no one has asked how long any given total population can be maintained over the long run. It is this second question that brings to light the true complexity of the population problem, and which shows that even the concept of an optimum population level is an inept fiction.

The mechanization of agriculture is unanimously advocated as the solution to meeting the world's food demands. What does this mean in entropic terms? Mechanization has meant replacing draft animals with tractors, i.e., shifting from solar (via chlorophyll photosynthesis) to terrestrial sources of low entropy inputs. Thus, viewed in entropic terms, the mechanization of agriculture is antieconomical in the long run. To secure our biological existence we increasingly depend on the scarcer of the two sources of low entropy.

Moreover, the problem of depletion of terrestrial stocks of low entropy is not limited to the mechanization of agriculture. Given the disproportion between the amount of energy available from the sun compared to that in the earth, the industrial phase of man's evolution will cease long before the sun stops shining. The higher the degree of economic development, the sooner the end will come.

What does all this imply? Present economic development and production are using limited supplies of available low entropy at the cost of future generations. Even if we realize the entropic problem, we may not be willing to give up our present luxuries. It seems mankind is doomed to have a short life.