The need for biophysical economics

Charles A. S. Hall
State University of New York, College of Environmental Science and Forestry. Syracuse N. Y.

We are all aware of the limits of conventional (neoclassical) economics (e.g. Hall et al. 2001) but a problem has been whether "internalizing externalities" is enough to resolve the issues. Quite a few of us think that we must start over in deriving a conceptual base for economics. One such possibility is biophysical economics, a description of which follows.

Biophysical economics is a basis for economic analysis that acknowledges, analyzes and uses the biological and physical (as opposed to social) properties, structures and processes of real economic systems as its conceptual base and fundamental model. It acknowledges that the basis for nearly all wealth is nature, and views most human economic activity as a means to increase (directly or indirectly) the exploitation of nature to generate more wealth. As such, it focuses on the structure and function of real economies from an energy and material perspective, but often considers the relation of this structure and function to human welfare and to the money (i.e. dollar) flows that tend to go in the opposite direction to energy (Odum 1972). From a biophysical perspective, one's job is viewed as trading one's time at work (the monetary value of which is related to the energy flows of society controlled by the individual) for access through salaries to the energy flows of the general economy. This "general economy" contains goods and services created from the extraction of energy from the earth in anticipation of some demand for them. At present, each dollar we spend requires roughly 12,000 Kjoules (about an 8-oz. coffee cup's worth of oil or equivalent energy) to generate the good or service purchased. With economic inflation, the energy per dollar decreases over time so that in 1970, one could receive about ten times more energy (as used to generate goods and services) per dollar than he or she could today. The ice cream that fueled my paper route in 1954 cost only 5 cents, but required for production roughly the same amount of energy as today.

Figure 1 is my perception of the simplest diagram that one could use to represent a real economy, although it is far more complex and infinitely more accurate than that what is given in most economics textbooks. It includes (from left to right): (1) energy sources (principally, the sun) that are essential for any economy; (2) the material that circulates upon the earth's surface through natural and semi-natural ecosystems; and (3) the human-dominated steps of exploitation, processing, manufacturing and consumption. Black and white arrows show the transfer of material and energy through the economy. Raw materials are refined by human activities until the heat is dissipated and the materials are either released as wastes to the environment or recycled back into the system. From this diagram, one could argue that the most important activity of the economic process is the proper functioning of the hydrological cycle, since virtually all economic production and manufacturing are extremely water-intensive. From the standpoint of a traditional economist, the hydrological cycle is not important because we pay very little for it. A biophysical economist, on the other hand, would argue that it is critical for many reasons and that it is only because we can extract its services from nature at little direct monetary cost that we can have the high generation of wealth within today's economy.

Production functions from a biophysical perspective

The source of wealth, according to economists and their explicit mathematical production functions, has evolved over time from an emphasis on land to an emphasis on labor to an emphasis on capital. From the perspective of biophysical economics, all three of these miss the boat entirely, for each of these factors is an imperfect representation of the dominant energy source that does the actual economic production for the economy at the time being considered. For example, hunter-gatherer societies obtained food using the energy of each individual's muscular activities and the force-concentrating technologies of spear points and knife blades. The labor of artisans generated items exchangeable for food and other commodities. The concentrated energy of fire led to a large expansion in the food that people could eat, a reduction in the pathogens in that food, and the use of metals. Farmers redirected the solar energy of ecosystems to human mouths so that land became a source of wealth as emphasized by economists prior to the industrial revolution. The energy of elevated water and fossil fuels generated the basis for wealth during the 19^{th} and 20^{th} century. Over time, landed gentry with access to large solar collectors were replaced by new industrialists who took their place at the top of the financial ladder. Therefore, Quesnay was correct for the time and place in which he lived, when land-derived capture of solar energy generated the most wealth. Adam Smith was correct for the time and place in which *he* lived, when labor was increasingly the main way to generate wealth. Perhaps neoclassical economists are correct to put the focus on capital, i.e. the use of machines and ancillary equipment to do the job, or should it instead be on the energy that actually does the work? What all of these "mainstream" production functions fail to emphasize is what every biophysical economist knows to be the truth: it is the *energy* that does the work of producing and distributing wealth, whether that energy is derived from land, labor or capital-assisted fossil fuels. Ayres (e.g. 2005), Kuemmel (e.g. in Hall et al. 2001) and Hall and Ko (e.g. 2004) have shown that the production of wealth in industrial societies is almost perfectly a linear function of the energy use in those societies, and that the correlation gets tighter and tighter when proper corrections are made for the quality of the energy used (e.g. coal vs. electricity) and for the amount of energy actually applied to the process (e.g. electric arc vs. Bessemer furnaces). Much, perhaps most, technology is ultimately about these things.

It may seem obvious now that wealth is generated by the application of energy by human society to the exploitation of natural resources. Nature generates the raw materials with solar and geological energies, and human-directed "work processes" are used to bring those materials into the economy as goods and services. These processes have been made enormously more powerful over time through technologies that are mostly ways to use more or higher quality energies to do the job. To construct a production equation from a biophysical perspective, energy would be the first element to be considered because it is the most important factor – more important empirically than *either* capital or labor (Hall et al. 2001). It should be emphasized that this view does not negate the importance of human preferences or of the market as a means to allocate goods and services. Rather, it focuses on the source of those goods and services and on our increasing vulnerability to the depletion of the critical high-grade fuels that we rely upon so heavily (Hall et al. 2003, Hallock et al. 2004).