

## TOWARD REFINED INDICATORS OF SUSTAINABLE DEVELOPMENT

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My remarks highlight the misleading signals that are generated when standard neoclassical models are used to indicate economic growth and development. I wish to build on the now accepted fact that anthropogenic activity, what has been descriptively termed "technometabolism," has grown in scale to the point that it rivals in environmental impact some of the earth's natural systems. I will argue that the dangers in this level of activity stem not only from the massive drawing down of natural materials that this activity accomplishes and from the severe ecological stresses that can be placed on the assimilative capacity of ecosystems to deal with anthropogenic wastes, but also that the alarm signals that should sound when our actions are imprudent are themselves muffled by our neoclassical economic models. The couplings between economic reckoning and global ecological threats are weak or nonexistent. This problem leads to an unjustified optimism that environmental problems that accompany economic development in the less developed countries will gradually self-correct; that countries can "grow themselves" out of environmental despoliation. Two definitions of "sustainability" will be examined; one is reflective of environmental policies based on neoclassical concepts; the other suggested by the emerging field of ecological economics. Following Daly and Cobb, I shall refer to the first definition as "weak sustainability" and the second as "strong sustainability." Finally, I will suggest that by strengthening the connection between ecology and economics the information necessary to redirect technology in sustainable directions can begin to be generated. This will require new models of ecosystem health, enlightened public policies that can respond more quickly to indicators of ecosystem stresses, and a renegotiation of efficiency/equity tradeoffs.

### THE HUMAN SPECIES AND "TECHNOMETABOLISM"

Whereas the vast majority of terrestrial organisms have always survived on inputs as they found them of food, water and oxygen, along with inherited behavioral patterns programmed in the genetic code of each species, our species,

as early as 65,000 human generations ago, tapped additional sources of materials and energy by means of "know how" embodied in human cultures. The Promethean advantage of this unique social invention, "technometabolism," (Boyden and Dovers, 1989, pp. 63-69) doubled the daily energy consumption level for an individual human being from an average somatic or biological requirement of 2400 Kcal or 10 megajoules per day, here designated one Human Energy Equivalent (HEE) to 4800 Kcal or 2 HEE. Fire driving, for example, as a hunting strategy augmented biological somatic energy consumption with extrasomatic energy simply burned off and released in connection with the hunt. It is estimated that this phase of technometabolism, more commonly known as the "hunter-gatherer" phase of human existence, lasted until about 400 generations, or about 12,000 years ago.

The next 190 plus generations of human existence witnessed such social inventions as occupational and social stratification and warfare, and experienced great increases in contagious diseases. Cities emerged but remained until fairly recently a relatively small factor in population distribution. The vast majority of persons lived out their lives in rural settings. Technometabolism of this period was marked by the utilization of new materials: timber and other building materials, fiber, metals. Still, it is estimated that during all of this period, what Boyden and Dovers call the Early Urban period, which led up to the Industrial Revolution, per capita energy use would rarely have exceeded three HEE per day or 7200 Kcal/day.

Just eight generations ago, when the planet contained an estimated eight hundred million people, technometabolism experienced a quantum increase (Coale, 1974, p. 43). Based largely on the tapping of fossil minerals, first coal, then oil, technometabolism skyrocketed, growing to its current energy consumption level of fifty-six HEE ( $1.344 \times 10^6$  Kcal per capita) in the developed countries and six HEE ( $1.44 \times 10^6$  Kcal per capita) in the developing countries. (The world's largest per capita consumer of energy, the USA, currently consumes 100 HEE.) All in all, there has been a ten thousand fold increase in human energy use since the transition to domesticity, 400 generations ago (Boyden and Dovers, 1989, p. 65).

With the enormous increase in energy and material inputs into the technometabolic process has gone an accompanying generations of waste. While

someone half humorously noted that "the solution to pollution is dilution," current levels of waste generation threaten to exceed the limits of the earth's assimilative capacity to serve this cleansing function.

### DEVELOPMENT AND ENVIRONMENTAL QUALITY

If such environmental limits have been exceeded, however, a persuasive case can be made that we are not in an ideal position to confirm the fact. This is due to an inadequate coupling between our measures of economic activity—neoclassical economic models—and our tools and techniques for measuring environmental quality. In a recent article in the journal *Science*, a group of influential economists headed by Kenneth Arrow identify these weak linkages between economic growth and the carrying capacity of the earth and the resilience of the environment (Arrow *et al.*, 1995).

Development theory has generally taken as axiomatic the assumption that economic growth is good for the less developed countries even though the initial stages of such growth are typically accompanied by marked decreases in environmental quality. "It has been observed," these economists note, ". . . that as income goes up there is increasing environmental degradation up to a point, after which environmental quality improves." This relationship has come to be called the "inverted U curve."

Environmental monitoring has shown that the factors of environmental quality that are most likely to improve with economic growth include levels of sanitation and purity of drinking water, along with reductions in particulates, sulphur oxides, nitrogen oxides, carbon monoxide and fecal coliform. If these were the main environmental costs associated with economic growth in developing countries, the inclination to "grow oneself out of the problem," would be defensible. Arrow and his colleagues go on, however, to offer critical caveats. The inverted U curve does not directly provide a clear signal as to the quality of the environmental resource base itself. Thus, for example, the curve has not been shown to be valid for long-term and more dispersed factors such as CO<sub>2</sub>, nor is it likely to hold for soil depletion, loss of forest cover and other ecosystem processes. The inverted U curve says nothing about system-wide consequences of emission reductions such as when reductions of one pollutant lead to the increase of another or reductions of pollution in one country induce increases in adjoining

countries.

The limitations of the inverted U curve are particularly disturbing when, as already noted, levels of technometabolic activity have increased to the point of rivaling some of the earth's own processes, such as the hydrologic cycle, the ozone radiation shield, and temperature regulation of global ambient temperatures. While conventional wisdom leads us to an intuitive conclusion that there are limits to the carrying capacities of these global systems, we are left largely in the dark as to whether such capacities have been or are being reached because we lack evidence that the economic signals that are generated in the case of isolated individual pollutants are even connected to the global and/or long term effects of technometabolic activity. Earth's carry capacities are not fixed. The physical and biotic environments are not independent. Technological practices, human preferences, and structures of production and consumption all modulate these carrying capacities.

While no single estimator of global carrying capacity is definitive, Vitousek and colleagues (1986) have estimated that at present 40 percent of the Net Primary Product (the total food resources on Earth) resulting from solar insolation is intercepted and utilized by one species, *Homo sapiens*, and its auxiliary species. Such a statistic, even granting significant leeway for error, is sobering—although it must be admitted that what one does with such a number is far from clear.

Arrow and colleagues have recommended that an alternative measure of human environmental impact be developed and utilized, namely, one based on ecosystem resilience. As defined, ecosystem resilience identifies types and levels of disturbances and insults that an ecosystem can absorb before the system flips from one stable state to another (Holling, 1985). Additional ecological theory needs to be developed relating these ecosystem flips to such factors as loss of biodiversity, depletion of groundwater reservoirs, loss of heterogeneity of ecological functions, loss of ground cover, absorptive capabilities of water courses, and many other factors best investigated by ecologists.

#### TYPES OF SUSTAINABILITY

But here we return again to the underlying theme I am developing. The

connection between the ecological knowledge concerning ecosystem resilience that we are generating and the economic indicators that would foster rational adjustments of technometabolic action in the face of such ecological knowledge is weak at best. Accordingly, calls for "sustainability" are issued in contexts that are bereft of clear ideas of what it is that is to be sustained as well as of coherent models for generating, measuring, and integrating such indicators of sustainability into acceptable economic practices.

Two definitions of sustainability are currently in common parlance. The first reflects the fact that neoclassical economists are somewhat nonplussed by the difficulties of dealing with issues of intergenerational equity, resource depletion, and ecosystem degradation and/or resilience. They propose to encapsulate these diverse factors in a definition that is succinct and conceptually elegant. A second definition of sustainability, generated by practitioners of "ecological economics," an emerging paradigm to rival neoclassical market economics, includes those factors identified above as missing in the neoclassical conception of economic development. This approach aims to be responsive to the issue of ecosystem resilience.

Daly and Cobb (1989, pp. 72 and 73) choose to designate these two definitions of sustainability as "weak" and "strong." Nobel laureate Robert Solow (1991, p. 181) provides us with a succinct definition of sustainability in neoclassical terms. His definition of sustainability, of the kind we are calling weak, states that our obligation to embrace a norm of sustainable human action "is an obligation to conduct ourselves so that we leave to posterity the option or the capacity to be as well off as we are. Norton (1996, 1995, 1992) has been influential in this discussion. According to Solow, there is *no specific* object to the goal of sustainability. What we are transmitting to our heirs is *ageneralized* capacity to be as well off as we ourselves are. Crucial to this definition is the assumption that all resources, including all ecosystems—the ones we consume and the ones we pass on—are "fungible." That is to say, substitutes can always be found for every resource and ecosystem that our technometabolic activities utilize. Perfect intersubstitutability means that the "bequest package" (Norton, 1995, p. 116) that we pass on to our heirs is *unstructured*. "Monetary capital, labor, natural resources, and ecosystem functions are interchangeable elements of capital." There is no separation of *human generated capital*, those resources generated by technometabolic activity, from so-called *natural capital*—those

functions associated with ecosystems, products of natural metabolism measured by Net Primary Product (NPP). Instead, fungibility solves the problem of intergenerational bequests in as unstructured and varied a set of ways as do humans when they realize their individualized and idiosyncratic preference schedules.

Ecological economists take issue with the amalgamation of capital into a single category. "They argue that certain elements, relationships, or processes of nature represent irreplaceable resources, and that these resources constitute a scientifically separable and normatively significant category of capital—natural capital" (Norton, 1995, p. 115).

The issue of ecosystem resilience becomes critical according to this definition. Ecological economists call for the bequest package for posterity to be a *structured* one. The makeup of this structured bequest package presents challenges to economic theory. Since the neoclassical models fail to disaggregate technometabolic and natural capital, new models which do are called for. While committed to articulating such models, Norton (1995, p. 119) believes it is too soon to "call the ecological economists' approach to intertemporal time preference a 'new paradigm'."

Following a two-tiered approach devised by Page (1977, chapters 7-9), Norton (1995, pp. 119-122) argues that a start toward a decision procedure for ecological economics that reflects the structured bequest package called for by strong sustainability would combine elements of the neoclassical market paradigm with politically generated restraints on the unfettered market informed by ecologically generated information concerning ecosystem health and resilience. These latter considerations would act as second-tier limits on economic activity in cases where ecosystems are approaching breakdown or shifts in state, or where certain amenities considered valuable by the citizenry but undervalued by standard economic measures, are threatened with elimination. Scenic vistas, endangered species, ecosystem resilience, etc., would all fit into this category.

The structure of the decision procedure according to the two-tiered approach would still recognize the primary role of the market in the acquisition and disposition of primary materials, the production of goods and services, and the generation of capital. Fungibility would still apply. This would all be what

we are calling tier one activity. Tier two brings into play non-economic concerns. Here the ecologist's knowledge would inform what must ultimately be a political process of social negotiation between manufacturing enterprises and the body politic. Critical factors to be identified and tracked would involve questions such as: (1) Is an ecological system degraded by this technometabolic activity? (2) If so, how quickly would the ecosystem revive if this activity ceased—one year? One decade? One generation? One life human lifetime? One century? One millennium? Or perhaps never? (3) What is the scale of this activity: localized? One community? One bioregion? One watershed? Global? Norton has argued that at the point at which the activity involves a time frame of one human lifetime for ecosystem regeneration and on a scale of one ecosystem (e.g., the Chesapeake Bay in the USA), the technometabolic activity should be flatly proscribed. At this point, by political action the market becomes completely fettered. One could say that the non-economic factors have trumped all neoclassical economic considerations. The current ban on CFCs, adopted at Montreal, might come to be seen as an early prototype of the second-tier restraints we are discussing.

It is not my purpose here to develop the details of the two-tiered decision procedure. Here again reference is made to *The Journal of Ecological Economics* as a good place to track the discussion of this and other contributions to a new ecological economic paradigm which will be able to address the insensitivity of neoclassical economic theory, with its principle of fungibility, to the irreversible character of some of the forms of material production and consumption that the standard model would license. One is reminded of Arthur Okun's remark, made a generation ago but perhaps even more accurate today than it was then: "The market needs a place and the market needs to be kept in its place" (Okun, 1975, p. viii).

## CONCLUSION

We have argued the case for strong sustainability. The justification rests on the fact that weak sustainability, a concept totally connected with neoclassical market economics, fails to disaggregate the factors of technometabolic or human made capital from that of natural capital. As a result the principle of intersubstitutability that recognizes the potential for the creation of substitutes for depleted materials or processes is inappropriately applied when extended to forms of natural capital such as ecosystems, watersheds, global hydrologic cycles,

atmospheric ozone shielding, global ambient temperature regulation, and human caused biological species extinctions. Here, the issue of ecosystem resilience, so critical to maintenance of human life on the planet, is simply not addressed. The inverted U curve is thus not a rational basis for encouraging development in the developing countries. The hope that eventually the despoliation of the environment created by rapid development will be self correcting as economic development approaches levels currently identified with the developed countries is without an ecological basis of support.

In arguing for strong sustainability, we embrace the position that sustainability is not just an economic issue in the neoclassical sense. It is not just an issue of technological actions that have gone too far in defining us as a species. Sustainability is comprised of an institutional triangle, with economics, ecology, and socio-cultural institutions at each apex. Each step toward a sustainable future involves a social negotiation between public and private sectors, between citizens and consumers, between political processes and structures and the market. Because the market fails to generate the necessary signals warning of many ecological insults, it must be supplemented by political processes that include among their functions robust means of measuring and explaining ecosystem health.

Because human identity limited to the role of consumer is a pathetic attenuation of human potential, the importance of citizen involvement in the generation of public policy must be encouraged and praised, not diminished and scorned. Because a post-Enlightenment emphasis upon atomistic individualism has too long grounded us metaphysically as solitary bundles of preferences, we must recapture the classical sense of the *polis* as the true source of our individuality. A structured bequest package passed on to our heirs, containing unspoiled vistas, clean environments, decent human settlements, and resilient and functioning ecosystems, will be testimony that the technometabolic adaptability of our species has once more risen to the challenge that we exist on our wits. One is bound to say at this point that such a monumental change in our technological activities as these goals would call for is far from certain.

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energy left after subtracting the respiration of primary producers (mostly plants) from the total amount of energy (mostly solar) that is fixed biologically. NPP provides the basis for maintenance, growth, and reproduction of all heterotrophs (consumers and decomposers); it is the total food resource on Earth.