How do economists define sustainability?

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Concepts integral to the contemporary idea of "sustainability" have always been central to economics. Economics is, after all, the study of how humans allocate scarce resources. Adam Smith inquired in 1776 into how human populations can produce greater standards of living from a fixed set of inputs through a division of labor coupled with trade in the outputs of that labor guided only by the "invisible hand" of individuals' collective free decisions, based on their own self interests, to buy or to sell and for how much. In the mid 1800s John Stuart Mill and Thomas Malthus debated whether the growth of such a system of production and reallocation could be sustained as populations grew but the fixed base of natural capital needed to sustain them remained constant. In the 1930s and 40s, John Hicks formalized a concept later called *Hicksian income*, that describes the level at which an individual, a household, or a whole economy could consume and still leave their stock of productive capital intact so as to be able to keep on consuming at that level indefinitely.

Yet, today's notion of sustainability—as popularized by the Brundtland commission in 1987 as the ability "*to meet the needs of the present generation without compromising the ability of future generations to meet theirs*"—comes most directly out of ecology, where the concept is both tangible and intuitive. We can observe an ecosystem at carrying capacity, with population levels sustained in a steady state dynamic equilibrium. We can also observe an ecosystem collapse. The lessons for humankind seem straightforward enough: we can either maintain a dynamic equilibrium within the planet's carrying capacity, or we can consume beyond its capacity and cause our civilization, the human species, or even the planetary ecosystem to collapse. When framed in such broad terms, "sustainability" is something that everyone can support. Indeed, the great appeal of "sustainability" as a policy goal lies largely in its lack of specificity, in its fluidity and ambiguity, in its ability to project different messages to different constituencies and thereby allow for a degree of political consensus. Who, after all, would be *against* "sustainability" and thus, by implication, *for* the end of the world as we know it?

Left to such breadth and flexibility, however, the concept of sustainability becomes far less useful if we want to apply it as a decision-making criterion within a specific policy context (such as the one before us today over modifying the capacity of an aviation fleet to utilize biofuels.) Economists have therefore sought to craft sharper definitions of sustainability, largely by focusing on three big questions implied by the conventional notion of not compromising the ability of future generations to meet their needs. Those questions are, to paraphrase Lele and Norgaard (1996), what exactly is to be sustained, over what time period, and with how much certainty?

What is to be sustained? For economists, the first challenge in creating a useful definition of "sustainability" has been to identify just what should be sustained or, mathematically speaking, what value (or values) should be non-decreasing over time. Were we asked to create an indicator of sustainability, what would we measure? Robert Solow (1991) argued that what needs to be sustained is our "*generalized capacity to create well being*", while emphasizing that this capacity need not consist of "*any particular thing or any particular natural resource*", since resources are at least to some degree fungible or substitutable. If one resource were to run low, we could draw upon another to maintain our well being.

Most economists would agree that ultimately what we are interested in sustaining is our well being as humans on planet earth. Ecologists and others might argue for a broader measure that explicitly includes the well being of other species or even geophysical processes. While economic concepts of well being, such as aggregate utility or social welfare, may perhaps appear anthropocentric, they in fact encompass much of the planet, given our dependency on natural capital and the services it provides. Actual economic measures of well being are, however, imperfect. They include aggregate indices such as GNP, consumption, demographic or public health indicators, and quality of life or "happiness" indices. Within a specific sector such as agriculture we can get a bit more precise, with indices such as available calories or nutrients *per capita*. However, in some sense, these are just outputs. To assure that these measures of well being are non-decreasing over time, it is essential to focus on sustaining our "capacity to create" well being, which on the full scope of our capital base, including natural capital, physical capital, human capital, social capital and intellectual capital.

The second part of Solow's formulation—that about substituting resources—is absolutely essential to conceptualizing sustainability of our capital base. Economists have long differentiated resources based on whether and how much their stocks are depleted when they are use. For simplicity, there are renewable resources (like fish or forests), non-renewable but durable resources (like fresh water or metals, which can to some extent be recycled), and non-renewable non-durable resources (like oil or natural gas, which cannot be recycled at all). A finite non-renewable non-durable resource, like oil, will eventually get used up. Still, economist John Hartwick in 1977 suggested a strategy whereby using up a non-renewable resource could still be considered "sustainable". If, in the process of consuming the resource, the value of what is consumed is re-invested into some other form of capital—such as a renewable resource, human capital, or intellectual capital—then the net value of our collective capacity to create well-being will not decrease. The same rule applies in the long run to non-renewable durable resources (like copper or steel). They likewise cannot last indefinitely, since thermodynamically no recycling process can recover 100% of the resource, but they can be drawn down over a much longer time frame if routinely recycled. The sustainability rule for renewable resources, like forests or products of agriculture, is more straightforward: if we keep the harvest rate in balance with the growth rate, its capacity to create well-being can be maintained indefinitely. It must be noted that investments in intellectual capital—knowledge or technology—can be particularly important for achieving sustainability. Historically it has shown a tendency to increase, in some cases quite dramatically, the productivity of all other forms of capital, thus requiring less capital to maintain the same level of well-being, sometimes much less. Greater productivity through gains in knowledge is effectively how we have (repeatedly) escaped the dilemma posed by Malthus 150 years ago.

Substitution between resources is one of the most highly contentious issues in the debate about sustainability. First of all, tradeoffs between the use of different resources or types of capital are seldom equivalent and transitions may not be smooth. Moreover, the prospect of complete exhaustion or loss of some convinces us that not everything is fungible: there are resources small and large that cannot be replaced with a substitute, whether essential ecological processes, coastal lowlands threatened with rising sea levels, species threatened with extinction, or unique landscapes such as Yosemite or Yellowstone. Finally, different resources are owned and controlled by different countries, industries, or individuals. Shifting from reliance upon one to another can have enormous implications for who can capture rents, an issue over which wars have been fought throughout history.

Over what time period? Economists have observed that levels of interest rates or, more abstractly, of social discount rates mean we significantly undervalue the future use of resources relative to their use in the present. At first look, it may appear as if we only value the use of resources while we are alive. This has led economists to recognize the time aspect of sustainability as a moral question, a question of intergenerational fairness. It is, fundamentally, about distributive equity between those who value resources today and those, yet unborn, who will value those resources tomorrow. The current generation's inability or unwillingness to appreciate future generations' well being has been called a "tyranny of the present". Fortunately, theoretical models of the economy, imbued with some measure of altruism toward one's direct descendents combined with a general "existence value" of the future of the planet, show future generations no worse off than the present (Asheim, 1991).

With how much certainty? Finally, the third crucial aspect of defining sustainability is the level of certainty over how our well being and our capacity to maintain it is sustained. Economists have clarified what factors in the calculation are impossible for us to know with certainty. We cannot know even who the future generations are going to be, or even how many there will be. We cannot know what their intrinsic preferences will be: what will they value? We cannot know what technologies will be available, how efficiently they will be able to utilize what resources and thus what the relative scarcity of different forms of natural and physical capital will be. The best guidance we can take today is to maintain reasonably safe lower bounds on the levels of natural capital with which we have been endowed, to invest sufficiently in the potentially most durable forms of capital—the human and intellectual—and to avoid imposing too much certainty on the future, in the negative sense, by not introducing too many completely irreversible changes.