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## Measuring sustainability: needed—an interdisciplinary approach to an interdisciplinary concept

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### 1. Introduction

The potential for high rates of population growth, increasing incomes, and changes in technology to disrupt the environmental life support systems that underlie human well-being is an important research topic for both natural and social scientists. To date, the two groups have not generated a consensus. Generally, natural scientists tend to argue that the threat to human well-being is more severe than social scientists recognize.

One reason for the lack of agreement is the difference in system boundaries and environmental indicators used by natural and social scientists. Social scientists focus on the use of life support (e.g., the demand for natural resources or the emission of waste products) while natural scientists focus on the ecological, chemical, or physical changes in natural systems caused by human activity. Despite the inputs of economists and ecologists, the emphasis on resilience drops Arrow et al. (1995) into this same dichotomy.

We argue that the sustainability of human systems can be understood by integrating concepts and indicators proposed by social and natural scientists. Sus-

tainability is based on the balance between the ever-changing types and quantities of environmental life support used by society, and the long-run ability of natural ecosystems to provide life support. This balance can be evaluated by criteria that combine the strengths of social indicators, which measure the economic and technical factors that determine the use of life support, and natural science indicators, which model the long-run ecological effects of using life support.

### 2. Strengths and weaknesses of economic and ecological measures of sustainability

A series of scientific, economic, and political concerns has generated significant interest among economists in the issue of sustainability. Recently, much of this research focuses on the relation between income and the use of environmental life support. This relation, known as the environmental Kuznets curve (EKC), posits that the use of life support (either the consumption of natural resources or the emission of wastes) initially increases with income. Beyond some point, further increases in income reduce resource depletion and waste production.

This approach towards measuring sustainability

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has several important strengths. Most importantly, the EKC focuses on the factors that *change* the demand for environmental life support. The emphasis on change is necessary because the consumption of natural resources and emission of wastes changes rapidly over relatively short periods. For industrial nations, crude oil is a critical component of environmental life support—100 years ago it was not. Because of such changes, it is not possible to calculate the carrying capacity for human populations by dividing sustainable levels of life support by per capita demand (as is theoretically possible for non-human populations). Another important feature of the EKC is the empirical analysis of many forms of natural resources and environmental degradation (Grossman and Kreuger, 1991; Shafik and Bandyopadhyay, 1992; Shukla and Parikh, 1992; Beckerman, 1993; Panayotou, 1993; Cropper and Griffith, 1994; Kaufmann et al., 1994; Seldon and Song, 1994).

Despite these strengths, EKC's have several weaknesses (Kaufmann et al., 1994; Stern et al., 1994; Arrow et al., 1995). Contrary to the distorted claims by some, findings that high income levels reduce the demand for natural resources or the generation of wastes do not indicate sustainability. EKCs cannot measure sustainability because they lack a spatial or temporal component. The environment's long-run ability to dilute and detoxify anthropogenic wastes depends largely on the quantity that each unit of landscape must process (concentration). Yet, many of the EKCs for anthropogenic pollutants focus on the quantity of pollution emitted (emissions). For example, Seldon and Song (1994), Shukla and Parikh (1992), and Panayotou (1993) specify *emissions* of sulfur dioxide as the dependent variable even though it is the *concentration* of SO<sub>2</sub> in the atmosphere or in precipitation that determines its ecological impact. Similarly, many EKCs ignore the temporal pattern at which natural systems generate life support. For example, Shafik and Bandyopadhyay (1992) examine the relation between income and the annual rate of deforestation without regard to the rate of reforestation.

The weaknesses of the EKCs are the strengths of ecological measures of sustainability. Many of these measures look explicitly at the impact of human activities on natural systems. Arrow et al. (1995) tout ecological resilience as “a more useful index of

environmental sustainability.” Certainly, this index does contain some important information about the sustainability of economic activity. Its most important strength may be its emphasis on non-linear and discontinuous change in ecological systems. Clearly, many of us think in linear terms and can be lulled into a false sense of security during earlier stages of non-linear change.

Nonetheless, there are many weaknesses of resilience which disqualify the claim that “Economic activities are sustainable only if the life support ecosystems on which they depend are resilient” (Arrow et al., 1995, p. 521). Because resilience focuses narrowly on ecological dynamics, measuring the “magnitude of the disturbances that can be absorbed before a system centered on one locally stable equilibrium flips to another” is not a meaningful measure of sustainability.

Why focus on the “flip” from one system to another? Such a flip may be only the most dramatic and rare of many causes for non-sustainability. Well before the system flips, human disturbances may reduce the ability of the natural system to provide life support. Such reductions may be less dramatic, but pose a more immediate threat than the “flip.”

The danger of emphasizing discontinuous change is reminiscent of the parable of the frog that sits still and dies in water which is heated slowly, but will attempt to jump out if placed into a boiling pot. For human societies, resource degradation is analogous to the slow heating of the water. Running out of oil sounds like a catastrophe and it is. But the threat to sustainability occurs well before oil is exhausted. As the oil resource base is depleted, society must recover its supply from ever poorer deposits. The use of lower quality deposits increases the amount of effort required to obtain oil and other forms of life support (Cleveland, 1991). Well before society runs out of oil, the economy would collapse because it is directing so much of its effort to obtaining oil.

Another problem with using resilience to measure sustainability is the notion of “locally stable equilibrium.” What aspects of the natural system are in equilibrium? Is it the population of a particular species or a set of species? Or is it some index of system performance, such as net primary productivity? And how do these stability criteria relate to the natural system's ability to provide life support? The

natural system's ability to provide life support depends on processes within the system, but these processes may or may not be related to local equilibria. As a result, the criteria for measuring stability cannot be defined based on our understanding of ecosystems alone.

### 3. Integrating economic and ecological approaches

Indices or relations based on economic or ecological concepts alone cannot be used to measure an interdisciplinary concept such as the carrying capacity for human populations. Instead, we need to combine economic and ecological analyses of specific aspects of environmental life support. Many of the ideas developed by economists can be used to identify the forms of life support used by human societies and the ease with which they can be changed. Many of the ideas developed by ecologists can be used to evaluate the ability of natural environments to provide this life support.

In combining these two approaches, we suggest that analysts abandon the notion of a society-wide sustainability index. The search for such a "Holy Grail" already has consumed the careers of too many talented scientists. As a dimensionless number, the label "sustainable" or "non-sustainable" has no meaning. Furthermore, there is little serious argument that current patterns can continue *ad infinitum*. Rather, the argument over sustainability concerns the costs and benefits of continuing current patterns and bearing the impact of non-sustainable activities or bearing the cost of changes designed to avoid a bottleneck on sustainability. For example, no one argues that we can emit ever-increasing amounts of greenhouse gases into the atmosphere for the next several centuries. Rather, the substantive argument concerns the impacts of such actions on natural and social systems and the impacts of actions that curb emissions.

Consistent with this need for policy-relevant information, ecological economists need to graduate to a less aggregated, more interdisciplinary, and more sophisticated notion of sustainability. Just as biologists found that the true information about evolution comes from understanding variation and not the per-

fection of the "ideal species type," ecological economists should realize that little can be learned from comparing society to some ideal (and imaginary) sustainable society. To learn about sustainability, we must identify non-sustainable aspects of society, quantify impacts of non-sustainable activities on natural and social systems, and quantify the impacts corrective actions.

To answer these more relevant issues associated with sustainability, ecological economists must integrate models for the use of particular forms of life support and the environment's ability to provide life support. We offer some of our ongoing efforts as examples. We have tried to understand the sustainability of food supplies by analyzing the myriad ways in which energy is used to grow food, how those patterns affect the long-run ability of the agricultural ecosystem to provide food, and how these changes affect the ability of the economic system to produce non-food goods and services (Gever et al., 1986; Cleveland, 1995). Similarly, we have tried to quantify the geological, economic, and political forces that determine the supply, demand, and price of oil, the environmental impacts of oil extraction, and what these changes imply about future patterns of energy use (Cleveland, 1992; Kaufmann, 1995).

Enough with theoretical arguments about sustainability indices! To study sustainability, pick a form of environmental life support, quantify the economic and ecological determinants of the temporal and spatial patterns of its supply and demand, and model these dynamics. Just do it!

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