I. The Sustainability Issue—Background

More than a decade has passed since the Brundtland Commission focused public attention on concerns regarding sustainability and sustainable development. According to this Commission's report, a sustainable path of economic development will "...meet the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

Since that time, the sustainability issue has appealed to a diverse, and often unrelated, collection of interest groups. According to Graham-Tomasi (1991), ".... just about everyone is on the sustainability bandwagon, and sustainability has come to mean all things to all riders on this bandwagon" (p. 82). For example, Murcott (1997) has identified 57 definitions of sustainable development since 1979. The Brundtland Commission's vision of sustainability continues to provide a useful point of departure for public debates on sustainability (President's Council on Sustainable Development, 1996).

Similar to the Brundtland Commission's vision of sustainability, we view an economy to be sustainable when the economic well-being of both the present and future generations is maximized. Economic well-being, however, goes beyond the traditional view of economic goods and services, such as food and clothing, to include goods and services often not bought and sold in markets, such as the services provided by the environment (e.g., recreation, safe drinking water, and scenery).

Sustainability also extends beyond the economic well-being of the current generation and reflects the ability of future generations to meet their needs. The well-being of current and future generations is linked by extending the traditional view of capital (e.g., buildings and machinery) to include farmland, forests, lakes, rivers, estuaries, and wetlands (natural capital) (Aldy, Hrubovcak, and Vasavada, 1998). From an economywide perspective, this definition of sustainability requires investing in an appropriate amount and mix of human-made and natural capital to ensure that both market and nonmarket goods and services are available to society. This includes not only direct investment in different types of capital but also investment in research and development (R&D) on technologies that can increase the production of goods and services at a lower cost.

Opinions diverge on whether the actual performance of many economies is consistent with this vision of sustainable economic development. For example, in the *Limits to Growth*, the current generation's (over)use of nonrenewable natural resources such as oil and coal adds pressures to those caused by a fixed land base to create a bleak outlook for future generations (Meadows and others, 1972). Specifically, according to this study:

> *If present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years.*

Simon, Weinrauch, and Moore (1994) provide a contrasting view on the availability of natural resources. They argue that the relevant measure of resource scarcity is price, where the highest priced resources are the most scarce. Based on an evaluation of trends in the real (inflation adjusted) price of key nonrenewable natural resources, they conclude that these prices exhibit a declining trend, casting doubt on the conclusions reached in the *Limits to Growth*. Similarly, Nordhaus (1992) concluded that price data for real resources did not indicate a major turn toward scarcity.

More recently, the broader concept of the "carrying capacity" of the environment has been added to the list of sustainability concerns. Carrying capacity represents a biological limit on the environment's ability to support human activities. For example, many of the services the environment provides are regenerative or renewable but may be exhausted from over-use if the use rate exceeds the natural regenerative rate. In effect, carrying capacity represents the limits to growth caused by society's reliance on and (over)use of both nonrenewable and renewable resources.

Some have argued that the Earth's capacity to carry populations may be hindered. For example, Pimentel and Giampietro (1994) have argued that agricultural productivity in the United States is already unsustainable "given current depletion rates of land, water, and energy resources." In addition, nitrates and pesticides were detected in surface and ground water in agricul-

tural regions including the Corn Belt, New York, Pennsylvania, Florida, and in at least 23 other States (National Research Council, 1989). This finding has contributed to concerns that current agricultural production practices have exceeded the environment's capacity to act as a buffer and assimilate fertilizers and pesticides before they leach into ground and surface water.

This divergence of opinions regarding the actual performance of economies as well as the requirements for an economy to be considered sustainable are shaped, in large part, by differences in perceptions regarding the substitutability between inputs, now and in the future. For example, Christensen (1989) argues that, in most cases, human-made and natural capital cannot substitute for one another. That is, an increase in output requires more of both human-made and natural capital. Along this line of reasoning, Daly (1990) argues that sustainability requires that: (1) harvest rates of renewable resources (e.g., fish, trees) not exceed regeneration rates, (2) use rates of nonrenewable resources (e.g., coal, gas, oil) not exceed rates of development of renewable substitutes, and (3) rates of pollution not exceed the assimilative capacities of the environment.

Solow (1992) argues that it is not possible to preserve every type of capital and suggests a weaker definition of sustainability where human-made and natural capital are allowed to substitute for one another. Under this definition of sustainability, traditional measures of income can be extended to account for environmental goods and services and the value of changes in the stock of natural capital. Weitzman (1997) has shown that this extended measure of income can be considered an indicator of sustainability. Because human-made and natural capital are allowed to substitute for one another, the only requirement for sustainability is that the overall stock of capital, rather than each type of capital, is not decreasing over time.[2]

[2]This requirement abstracts from population growth. A more precise sustainability requirement is that the overall rate of net investment plus the rate of technological change is at least equal to the growth rate of population.