NATURAL RESOURCES, ECONOMIC GROWTH AND SUSTAINABILITY: A NEOCLASSICAL PERSPECTIVE

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Summary

The terms "sustainability" and "sustainable development" became the watchwords of environmental and natural resource policy during the 1990s. The most commonly used definition of sustainable development comes from the World Commission on Economic Development's 1987 Bruntland Commission Report: "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

This definition is perhaps appropriately vague, in that it allows the discussion of sustainability to encompass a wide variety of environmental and natural-resource policy issues that are important to the well-being of current and future generations. In many ways, sustainability has acquired the distinction attributed by William Howard Taft to

the word "conservation" in the early twentieth century – many people are for conservation no matter what it means.

This chapter will focus on the contribution of neoclassical economics to our understanding of sustainability.

1. Introduction

At its heart, sustainability is concerned with human well-being over time and, in particular, with the ability of environmental and natural resources to sustain and enhance human well-being. This is not a new concern for either society or economics. Concern over the ability of agricultural land to provide an adequate food supply for a growing population played a central role in the development of economics as a separate discipline in the late eighteenth and early nineteenth century. At the turn of the nineteenth century, Thomas Malthus postulated a tendency for the human population to grow geometrically while agricultural output would grow arithmetically. The result was that the bulk of the population would necessarily live at a subsistence level.

Diminishing marginal returns to agricultural inputs played a key role in Malthus' argument. The classical economic theory of the time envisioned capital and labor being used in fixed proportions when applied to land. The law of diminishing marginal returns held that the marginal return to labor – that is, the increase in output from a unit increase in labor input – would decline as agriculture intensified with more units of this capital-labor mix applied to a fixed amount of land. Diminishing returns also applied to the extension of agriculture to previously uncultivated land since the best land for agriculture would be cultivated first. The declining marginal return to labor eventually would cause the agricultural output per worker to decline, putting downward pressure on wages. The human propensity to reproduce would expand the population until wages were driven to a subsistence level.

Malthus could not have foreseen the expansion of agriculture into new areas of the world, the mechanization of agriculture in the early twentieth century which freed land for food production for people rather than work animals, or the rapid increase in grain yields in the last half of the twentieth century. These developments have allowed, at least up to now, much of the world's population to escape the Malthusian population trap. In essence, technological developments combined with declining human reproduction rates, outpaced and overcame diminishing marginal returns.

Coal, rather than agriculture, fuelled the industrial revolution in the nineteenth century. In the mid-1800s, the impending depletion of the highest quality and lowest cost coal deposits raised concern about the ability to sustain increased productivity. However, by the turn of the twentieth century, petroleum was well on its way to replacing coal in many economic uses.

The development of the United States economy was driven in part by abundant supplies of a wide variety of natural resources – agricultural land, timber, coal, oil, water, and minerals. A broad concern over the depletion of these natural resources galvanized the American Conservation Movement of the late nineteenth and early twentieth centuries.

Rapid use of minerals following World War II and national security concerns at the beginning of the Cold War heightened the interest in minerals policy.

The 1960s and 1970s also saw a resurgence of interest in economic growth and environmental and natural resource scarcity, this time with a much greater emphasis on the environmental impacts of resource use and economic growth. A systems analysis study by the Club of Rome examined a global economy dependent upon a non-renewable resource and damaged by the accumulation of pollution. It found rather dire outcomes –overexpansion and collapse of the economy – if economic and population growth were not significantly curtailed. The two oil crises in the 1970s exacerbated concerns about resource scarcity, and it appeared as though the world economy might be approaching an era of increased scarcity of natural resource commodities. However, no such scarcity has occurred so far; most natural resource commodity prices have fallen since the mid-1980s, some quite substantially.

Concern about environmental resources has continued with increased emphasis on the basic life-support systems of the natural environment. Human use of natural resources and the environment has increased to the point where human activity can have rather substantial adverse impacts on the global environment. For example, the concentration of carbon dioxide in the environment has increased from the range of 270 to 290 parts per million in the pre-industrial period to 370 parts per million today. The current concentration is greater than at any time in the last 400,000 years. A doubling of atmospheric carbon dioxide from pre-industrial levels is expected in the latter half of this century.

Atmospheric carbon dioxide allows solar radiation to pass through the atmosphere but traps some of the heat re-radiated from the earth. Indeed, the "greenhouse effect" is what allows the earth to be warm enough to support human life. But increasing levels of atmospheric carbon dioxide are expected to affect global temperatures and global climate in a variety of ways. Some areas will warm more than others, and rainfall patterns will change. Some areas may benefit from longer growing seasons and more rainfall, while others may be devastated by rising sea levels. Global warming surely will test the adaptability of many species to new environmental constraints, exacerbating the loss of biodiversity from deforestation, desertification, and other human encroachments on natural ecosystems. The last two decades have seen the warmest average temperatures on record. The average temperature in Alaska has increased 7 degrees Fahrenheit in the last 30 years, presenting a variety of problems such as melting permafrost and the loss of millions of acres of forest to beetle infestation. While there may be other factors in global warming, there seems to be a consensus that at least some of them are anthropogenic.

This chapter examines the contributions of neoclassical economics to an understanding of the complex issues involving natural resources and economic growth. It begins by discussing the results of simple economic growth models that incorporate natural resources, and develops some insights into key issues of sustainability. The neoclassical framework is neither used as a synonym for laissez faire, nor as a synonym for unimpeded markets, nor with the intent of specifying a particular intertemporal objective function such as discounted present value. Instead, neoclassical economics is

taken to mean a method of analysis rather than a set of results. This method can be put to a variety of uses, and it need not exclude the analysis of interactions between the economy and the environment. Indeed, the neoclassical framework can be a useful place to begin to think about economic-environmental interactions, and it can provide a powerful argument in support of environmental protection.

It is fair to say that resource and environmental concerns are absent from a large share of the neoclassical growth literature. The most recent resurgence in this literature with the development of endogenous growth models is no exception. On the other hand, some of the work in neoclassical growth theory provides important insights into sustainability. Areas of research that warrant more careful examination include the transition from an economy based on stocks of non-renewable resources to an economy based on flows of renewable resources, the role of endogenous technological change in moving the economy along a sustainable path, a rigorous treatment of intergenerational equity and uncertainty about future outcomes, the incorporation of environmental assets in economic growth models, and the development of measures to evaluate whether or not the economy is following a sustainable path.

2. Neoclassical Models of Economic Growth

2.1. Capital-growth Model

The development of theoretical models of economic growth began in the 1950s with simple capital-growth models. Physical capital – buildings, machinery, equipment, and so on – is produced to be used as inputs in the production of final goods and services. Physical capital is durable in that it can contribute to production for some time after it is produced. At each point in time, production can be either consumed for current enjoyment, or saved and added to the capital stock to enhance future production and consumption.

Capital accumulation drives economic growth in the basic neoclassical growth model. Labor productivity, consumption per capita, and welfare increase with increased capital per unit of labor. Capital accumulation continues until the marginal productivity of capital – the increase in output from an additional unit of capital input – is equal to the rate at which society is willing to trade off current consumption for future consumption, i.e. the social rate of time preference.
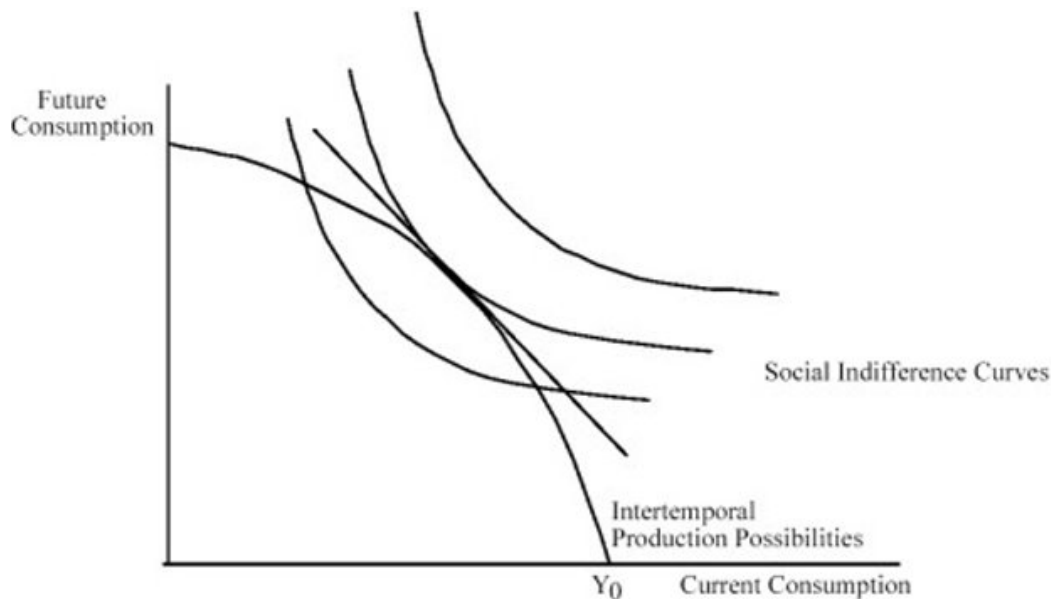
Figure 1: The social indifference curves represent society's preferences for different combinations of current and future consumption.

The basic analysis is depicted in Figure 1, where the social indifference curves represent society's preferences for different combinations of current and future consumption. Society is indifferent between combinations of current and future consumption that are on the same indifference curve. Consumption combinations on a given indifference curve are preferred to combinations on indifference curves below and to the left of that indifference curve. The slope of the indifference curve is the rate at which society is willing to trade-off current and future consumption, i.e. the social rate of time preference.

The intertemporal production possibilities curve depicts the combinations of current and future consumption that are available to the economy. Let Y_0 denote the maximum level of current consumption; it leaves no capital for future production so that future consumption is zero. If current consumption is less than Y_0, then the future capital stock is positive and future consumption is possible. The slope of the intertemporal production possibilities curve is the rate at which output increases as the capital stock left for future production increases, i.e. the marginal product of capital. If the marginal product of capital decreases as the capital stock increases, then the production possibilities curve is bowed out from the origin as depicted.

The optimal combination of current and future consumption occurs at the point where an indifference curve is just tangent to the intertemporal production possibilities curve. This is the highest indifference curve that society can reach given its production possibilities. At this point the slope of the production possibilities curve equals the slope of the indifference curve, so the marginal product of capital equals the social rate of time preference. If the marginal product of capital were greater (less) than the willingness to trade present for future income, then saving more (less) would improve social welfare by adding more to future (current) consumption than is necessary to compensate for the reduction in current (future) consumption.

Environmental and natural resources were first added to basic neoclassical growth models in the 1970s. The ideal growth model that incorporated natural resources should capture several important features – population, the growth or depletion of natural resources, the cumulative environmental impact of waste emissions (as well as the impact on renewable resources), investments in the assimilative capacity of environmental resources, the impact of environmental quality on producers and consumers, investment in physical and human capital, and expenditures on pollution control and recycling. In addition, the model should incorporate restrictions implied by the natural world, such as the first and second laws of thermodynamics, and it ought to allow for the uncertainty associated with the linkages between the economy and the environment.

Obviously, this is a rather tall order. The inclusion of only a capital stock, a natural resource, and an environmental quality variable already requires a minimum of three state variables. In general, it is technically difficult to characterize the qualitative features of a model with more than two state variables without making restrictive assumptions about functional forms or important relationships. Because of the inherent complexities, it is necessary for most growth models to focus on the most salient dynamic features of economic-environmental interactions. The simplified models are not intended to be taken literally, but are only a means of identifying important relationships and providing qualitative insights into the factors that affect the path the economy follows. Because outcomes can be sensitive to particular assumptions, it is important to examine alternative formulations to determine the robustness of qualitative results. The ability to explore alternative scenarios is one of the strengths of the modeling process.

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Bibliography

Dasgupta, Partha and Heal, Geoffrey (1974). The Optimal Depletion of Exhaustible Resources. *Review of Economic Studies, Symposium on the Economics of Exhaustible Resources*, 41, 3-28. [A classic paper that examines a capital-resource economic growth model.]

Heal, Geoffrey M. (1998). *Valuing the Future: Economic Theory and Sustainability*. New York: Columbia University Press. [This book provides a detailed overview of various economic growth models and examines the implications of the various intertemporal objective functions in different technological settings.]

Krautkraemer, Jeffrey A. (1985). Optimal Growth, Resource Amenities and the Preservation of Natural Environments. *Review of Economic Studies*, 52(1), 153-170. [This paper examines the effect of capital-

resource substitution and technological progress on non-renewable resource extraction in optimal growth models with resource amenities.]

Krutilla, John V. (1967). Conservation Reconsidered. *American Economic Review*, 57(4), 777-786. [A seminal paper on the growing importance of resource amenities and the issues they raise for efficient resource allocation.]

Krutilla, John V. and Fisher, Anthony C. (1985). *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources*, 2nd edition. Washington D.C.: Resources for the Future. [This book presents the results of research on the economics of natural environments spurred by Krutilla (1967). It includes chapters that develop the theoretical issues in the economics of natural environments that generate resource amenities, plus several case studies that apply the theoretical analysis to specific preservation-development decisions.]

Portney, Paul and Weyant, John P., (eds.) (1999). *Discounting and Intergenerational Equity.* Washington, D.C.: Resources for the Future. [A collection of papers with comments by discussants; it provides a thorough discussion of the numerous issues concerning discounting, particularly when there are very long-term effects of current decisions.]

Solow, Robert M. (1974). Intergenerational Equity and Exhaustible Resources. *Review of Economic Studies, Symposium on the Economics of Exhaustible Resources*, 41, 29-45. [A classic paper that examines the outcome of a capital-growth resource growth model when the social objective function is to choose the maximum sustainable consumption path.]

Biographical Sketch

Jeffrey A. Krautkraemer was born in Rapid City, South Dakota, USA. He obtained his B.A. in Economics (1976) from Washington State University, M.A. in Economics (1978) from Stanford University, and Ph.D. in Economics (1982) from Stanford University. He was a professor at Washington State University from 1981 to 2004. At WSU he taught undergraduate and graduate microeconomic theory as well as environmental and natural resource economics. He served as graduate program director from 1990 to 1994. He spent one academic year (1985-1986) as a visiting professor in the Department of Economics at the University of Washington and one year as a Gilbert F. White Fellow at Resources for the Future, Washington DC, USA. His research focused on natural resource economics, including natural resource scarcity and the environmental impacts of natural resource use. His work appeared in the *Review of Economic Studies, Journal of Economic Literature, Journal of Development Economics,* and the *Journal of Environmental Economics and Management*, and other journals. He served on the editorial boards of *The Energy Journal*, *Revista Mexicana de Economia y Finanzas (Mexican Journal of Economics and Finance)*, and the *Journal of Environmental Economics and Management*. He also served as an associate editor of the *Journal of Environmental Economics and Management* (1991-1992). He died of cancer in December 2004.