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Economic Considerations in the Framework of Sustainable Development Initiatives in Africa

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Abstract

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This paper elaborates key economic considerations essential to sustainable growth and development. While the economics literature on sustainable growth and development is rich and rapidly evolving, it is not always cast in a form that lends itself to basic policy alternatives. As a result, policymakers concerned with allied issues such as governance and good stewardship in the management of environmental and natural resources do not always weigh the importance of economic considerations, often with disappointing results. Ultimately, good policy depends on inclusion of clearly stated economic fundamentals if sustainable growth and development are to be realized.

As is now widely recognized, traditional measures of economic growth and development do not incorporate some of the broader issues essential to sustainable improvements in social welfare. Two factors are largely responsible for this limitation, both of which involve either the under-pricing, or the absence of pricing, of natural resources. One is the under-pricing of market activity due to the presence of environmental pollution. Although the literature on externalities suggests the use of corrective taxes and subsidies, for developing countries, the design of efficient pricing mechanisms and institutions is still largely unresolved, an issue that we seek to address in this paper.

The other limitation in standard measures of growth and development is the under-pricing of natural resources in a way that is consistent with their socially optimal replacement. In both instances, the absence of well-defined property rights is the principal reason why market prices are inefficient. The result is that growth and development that appear to be economically sustainable do not meet the broader test of sustainability once we account for the depletion of natural resources and take into consideration the impact of external costs.

The objective of this paper is to define the broader economic conditions under which growth and development can be sustainable, with applications to countries in Sub-Saharan Africa. Drawing on various economic models, we emphasize the role of exhaustible resources, environmental externalities, and renewable resource dynamics to sustainable growth and development alternatives. Ultimately, economic incentives built around a socially competitive allocation of resources are necessary if sustainable growth and development are to succeed.

Acknowledgments

This paper derives from the work of the Policy Consultative Group of World Resources Inc. The PCG was established to provide a forum for examining issues relating to Africa's environmental and natural resource management policies, and works in close consultation with the World Bank, U.S. AID, and other bilateral public and private development organizations. Its membership draws from representatives from academia, public development organizations, private non-governmental organizations, and individual experts with specializations and experience in a broad variety of policy issues in Africa. I express particular appreciation to Tom Fox, founder of the PCG at WRI, Tony Pryor in U.S. AID, Peter Veit at WRI, and Christine Elias of WRI. All conclusions drawn here are my own, as are any faults of commission and omission.

Much of the work of the PCG has focused on issues of governance in Africa, with particular emphasis on how governance helps to shape good stewardship in the management of the environment and natural resources in Africa. Members of the PCG have added much to the issue of governance, even though it may not always be readily evident in this paper. The motivation for this paper derives from the challenge of linking issues of governance to economics. It is a challenge in that economists have developed an approach to policy issues that often is highly technical, abstract, and seemingly removed from specific issues. Economics does, however, guide the allocation of resources, whether from the presence of market forces, or from intervention by various public agencies. The key is thus to draw from economics those issues that are pertinent to sustainable growth and development and to present them in as non-technical manner as possible, which is what drives the content of this paper.

One might ask more directly the question of how can one develop a closer integration between issues of environmental and natural resource governance and economic policy alternatives. The essential precondition for this to occur is to establish a framework for analysis that can be used to link these two domains into a more mutually comprehensible perspective. To do so requires that one draw on both the conceptual and empirical framework that has evolved in reference to environmental and natural resource utilization in a way that is more accessible to a broad group of specialists than has been the case up to now. If this paper succeeds to any extent in achieving this goal, then it will have been a success.

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I. Economics for Sustainable Development

Most societies seek in some fashion to achieve sustained increases in per capita income over time. In turn, the goal of rising per capita incomes is linked to some underlying standard of equity and social participation, along with the notion that these increases should be accomplished while preserving an economy's environmental and natural resource base, i.e., its natural capital.[1] This is what many people have in mind when they use the term sustainable development. Whether this conception of sustainable development is accurate, or even appropriate, to choices for increasing per capita incomes, it often seems to have more attention by environmental specialists than it has by economists. What is needed is a framework that is mutually understood and agreed upon by both economists and environmental specialists.

The purpose of this paper is to link economic incentives to the policy framework of sustainable resource use and economic growth, drawing on examples in Africa. While structural adjustment in Africa has been very much driven by economic considerations, the role of economics in achieving sustainable economic growth has been less clearly drawn. To redress this imbalance, I will emphasize the economic dimensions of natural resource use and the environment, and link them to policy choices for sustainable economic growth. The examples that follow are based on various models, which are presented here at a level that can be linked to various developmental initiatives.

Economies experience rising levels of per capita income through two fundamental processes: increases in the stock of resources, and improvements in the efficiency in the use of resources, i.e., technical change. By resources we mean the quantity and quality of land(which embodies both the environment and the stock of natural resources), labor, capital, and entrepreneurial skill. For many countries in Africa, weaknesses in the accumulation and management of physical and human capital often has meant greater reliance on natural capital. In turn, this has caused concern that the environmental and natural resource base will experience gradual deterioration as well.

In Africa, as elsewhere, whether or not economic growth is occurring, there is increasing pressure on the underlying natural resource base. This stems partly from population growth and partly from the economic and environmental policies thus far in place. The extent of these pressures on the environment and natural resource base leads many to the conclusion that economic growth is unsustainable. The challenge of sustainable economic development thus is to find ways to improve the management of the natural resource base while at the same time achieving higher

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[1] "Natural" capital refers to those resources within the environment that are extractable within the economy. They can be renewable or exhaustible. See Martin L. Weitzman, "Sustainability and Technical Progress", *Scandinavian Journal of Economics*, March 1997, 99(1), pp. 1-13; David Pearce and Giles Atkinson, "Measuring Sustainable Development," in Daniel W. Bromley, editor, *The Handbook of Environmental Economics* (Cambridge, Mass.: Basil Blackwell Publishers, 1995), pp. 166-181; Herman E. Daly and John B. Cobb, Jr., *For the Common Good* (Boston, Mass.: Beacon Press, 1989), pp. 69-76; Charles Perrings, "Ecological Resilience in the Sustainability of Economic Development", in Sylvie Faucheux, David Pearce, and John Proops, editors, *Models of Sustainable Development* (Brookfield, Vermont: Edward Elgar Publishing Company, 1996), pp. 231-252; Ismail Serageldin, Robert Goodland, and Herman Daly, "The Concept of Sustainability", in Wouter Van Dieren, Editor, *Taking Nature Into Account* (New York: Springer-Verlag, 1995), pp. 99-123; Richard Carpenter, "Limitations in Measuring Ecosystem Sustainability", in Thaddeus C. Trzyna, editor, *A Sustainable World* (London: Earthscan Publications, Ltd., 1995), pp. 175-197; and Salah El Serafy, "The Environment as Capital", in Robert Costanza, editor, *Ecological Economics* (New York: Columbia University Press, 1991), pp. 168-175.

standards of per capita income over time. Given the growing commitment of national governments in Africa and the international community to achieve sustainable growth and development in the region, we need to develop an analytical framework that can provide useful guidance to these initiatives.

II. Economic Growth and Development

Benchmarks of Growth and Development

Per capita income is the traditional benchmark for assessing policies for economic growth. While per capita GNP, and more recently, per capita GDP, serve as the usual yardsticks for per capita income, a more accurate measure is the use of purchasing power parity, or PPP, variants.[2] PPP measures of per capita income help to eliminate distortions in international comparisons that are caused by exclusive reliance on nominal exchange rates. Wherever available, we will use either the PPP level of per capita GNP or the PPP level of per capita GDP as our measure of per capita income.[3]

Where appropriate, we also will take into consideration other measures of development such as the index of human development published in the UNDP's annual Human Development Report.[4] Economists have long recognized that even a PPP measure of per capita GDP can not capture many of the broader dimensions of development, much less serve as the only yardstick of progress. While the use of a human development index adds an important dimension to our understanding of development, because many of the components in a human development index do not translate readily into market price measures, it makes is difficult to use such an index in guiding the allocation of scarce resources. In drawing this distinction, we thus begin with the fundamental question that development is a multi-faceted process that depends on the allocation of productive resources. The longer term challenge is thus to link benchmarks of human development to some measure of their economic as well as social value so that societies may make clear choices with full knowledge of the trade advantages that may be present. To say that this is the case where development is concerned in general today, or in a developing region such as Africa, it is clear that much remains to be done.

Accountability in International Aid, Trade, and Investment

Insofar as international aid, trade, and investment are concerned, resource commitments are made to the extent that they make differences in a country's level of per capita income along with a number of associated human development goals. If international aid in the form of grants or loans is the instrument, the first question is whether over the longer term donor resources produce measurable increases in per capita incomes of recipient countries. In turn, this first criterion is often linked to the notion of whether increases in per capita incomes are also economically

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[2] See, for example, *The World Bank Atlas, 1997* (Washington, D.C.: The World Bank, 1997), which contains estimates for the Gross National Product, Gross Domestic Product, and purchasing power parity estimates of GNP per capita. The PPP is defined as the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as one dollar would buy in the United States.

[3] It should be noted that even a purchasing power parity measure of per capita income does not capture all of the dimensions of development. Other indices, such as the UNDP Index of Human Development, can also sharpen our understanding. The basic HDI includes life expectancy, adult literacy, the combined school enrollment ratio, in addition to PPP Per Capita GDP. Yet to the extent that social indicators of development are positively correlated with purchasing power parity measures of per capita income, we will use for a per capita income measure as our principal benchmark for economic growth. It should be emphasized that PPP estimates of GNP or GDP per capita do not incorporate adjustments for changes in an economy's natural capital and environmental quality. For measurement and definitions used, see UNDP, *Human Development Report 1995*. (New York: Oxford University Press, 1995), pp. 134-135, and which began to incorporate gender consequences as well. The HDI is a simple average of the life expectancy index, educational attainment index and the adjusted real PPP GDP per capita index.

[4] *Op. Cit*., p. 122.

beneficial to donor countries in the form of expanded trade and investment choices.[5] International aid programs that fail to meet at least the first test eventually generate pressures for reductions or elimination of international aid in donor countries, a point that should be kept in mind as we examine the issue of sustainable growth and development.

For international trade and investment, the benchmarks are more narrowly focused because they already are framed within a market framework. Simply put, firms participate in international trade and investment only insofar as it is profitable for them to do so. If the economic framework is not conducive to trade and investment in a developing country, then either the developing country has adopted policies to discourage both domestic and international trade and investment, or they can only do so through some form of restructuring that may call for international support, such as through the IMF, the World Bank, or some other international public financial institution. Distortions in market prices can still create non-productive trade and investment, which is why structural adjustment is so important if resource allocation decisions are to result in positive rates of economic growth and development.

III. Economic and Environmental Perspectives on Sustainability

If the economic benchmarks for economic growth and development are fairly well established, what do we mean by sustainability? Goldin and Winters (1995) offer a straightforward general definition based on the Brundtland Report of 1987 and the 1992 Rio Summit: "'Sustainable' is often defined as development that meets the needs of present generations without compromising the ability of future generations to meet their needs."[6] If we add to this definition a few qualifications, we can then apply it to the current framework of sustainable development initiatives to derive policy alternatives.

It should be understood from the definition offered by Goldin and Winters that "meeting the needs" means that each generation seeks to maximize a level of satisfaction subject to the resource constraints and technology at each moment in time. As such, "sustainability" makes no prior stipulation on the level of per capita resource use over time, nor does it make any prior stipulation on the composition of per capita resource use. Moreover, sustainability also makes no prior stipulation on the level of per capita income, even though increases in per capita income is a major goal of most societies over time.[7] For our purposes, we will look at sustainability first of all within the context of the goal of increases in per capita income, and then in relation to the notion of a steady-state approach to sustainability.

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[5] The first criterion may be thought of as redistributive, while the second may be thought of as growth-driven. For tow countries, A and B, where A has a relatively high level of per capita income, the positive impact of the first criterion is met by $0<\delta A/\delta B<1$, while for the second, the positive impact may be judged by $0<\delta A/\delta B$ 1. In either case, $\delta A/\delta B<0$ and $\delta A/\delta B>1$ are ruled out by assumption, the former representing sheer incompetence and the latter representing economic exploitation. Ruling these out by assumption does not mean that they may be ruled out in practice.

[6] Alan Goldin and L. Alan Winters, *The Economics of Sustainable Development* (Cambridge, U.K.: Cambridge University Press, 1996), p. 1. See also United Nations, *Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, Vol I. Resolutions Adopted by the Conference* (New York: United Nations, 1992); World Commission on Environment and Development, *Our Common Future* (The Brundtland Report). (New York: Oxford University Press, 1987);

[7] This question has a long history in economic thought. In his *Wealth of Nations* (1776), Adam Smith suggested that once an economy has achieved a level of development, it would then enter into a steady-state in which the notion of continuous increases in per capita income would no longer be a goal. This theme is echoed in Herman E. Daly and John B. Cobb, Jr., *For the Common Good* (Boston: Beacon Press, 1989), and in Herman Daly's *Steady-State Economics* (San Francisco: W.H. Freeman, 1977). Daly argues that there are intergenerational equity issues that call for the adoption of a steady-state policy, a point that may have some support in developed countries, but which developing countries largely reject on the grounds that they are not yet developed.

One issue that arises in most discussions of sustainable resource use is whether per capita economic growth is a necessary part of the definition. Grossman (1995) offers an analytic framework that looks at the relationship between growth and environmental pollution that suggests that countries that achieve higher levels of per capita income also reduce the level of per capita environmental pollution, stopping short of concluding that economic growth is a necessary pre-requisite to sustainable growth.[8] Baldwin (1995), however, goes further and contends that economic growth is a necessary condition for sustainability to occur.[9]

The basis of these economic sustainability positions is straightforward: countries with low levels of per capita income do not enjoy access to the kinds of technologies that would enable them to adopt more prudent use of the environmental and natural resource base. Despite the efforts of the international development community to identify appropriate technologies, their adoption in developing countries makes economic sense only if there is an economic return to the resources necessary for their creation and utilization. The empirical evidence in support of this proposition is significant, and it is this perspective that drives most discussions of sustainable growth and development in the international development community.[10]

What does the notion of economic sustainability have to do with environmental sustainability? "Environmental sustainability" does not mean some straw counter-proposition to economic sustainability. What it does suggest is that human activity results in environmental degradation, be that in terms of excessive rates of extraction of natural resources, or in terms of irreversible changes in the environment. If natural resources are being extracted at a rate faster than they are being replaced directly or in terms of an equivalent, then this obviously is not sustainable. In turn, human activity produces environmental pollution, which lowers the quality of life, and which translates into altered rates of life expectancy.

Although environmental and natural resource use are major determinants of any sustainable path of economic growth and development, it does not follow that they are mutually exclusive choices. If environmental and natural resource degradation occurs with economic activity, it is due at least in part to the absence of pricing mechanisms that enable users and policymakers to make socially constructive choices. No pricing mechanism can eliminate environmental risks, but environmental quality can be better preserved in the presence of an efficient pricing system than in its absence.

Creating pricing mechanisms for sustainable resource use depends in turn on issues of governance. Good governance implies broad-based participation, and this remains the goal of many developing countries as they shift emphasis from reliance on the public sector to an expanded role of markets.[11] However, good governance by itself is not a guarantee that sustainable growth

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[8] Gene Grossman, "Pollution and Growth: What Do We Know?" in Goldin and Winters, *op. cit*., pp. 19-46).

[9] Richard Baldwin, "Does Sustainability Require Growth?", in Goldin and Winters, *op. cit*., pp. 51-76.

[10] See, *inter alia*, Robert Barro (1991),"Economic Growth in a Cross-Section of Countries", *Quarterly Journal of Economics,* 106(2): pp. 407-44; Greg Mankiw, D. Romer, and D. Weil (1992), "A Contribution to the Empirics of Economic Growth", *Quarterly Journal of Economics*, 107: 407-37;

[11] The World Resources Institute has devoted considerable attention to issues of good governance in natural resource use, and there is little question that in the absence of good governance that sustainable growth and development can occur. What must be understood by good governance is that it can only proceed when there is a system of clearly defined property rights. Together with civil rights, clearly defined property rights depend in turn on the strength of the institutions of civil society. See, for example, Derick W. Brinkerhoff and Peter G. Veit, "Democratic Governance and Environmental/Natural Resources Policy in Africa: Exploring the Linkages", (Washington, D.C.: Natural Resources Policy Consultative Group for Africa, World Resources Institute, October 1997); Allan Hoben, Pauline Peters, and Dianne Rocheleau, "Participation, Civil Society, and Development Assistance in Africa", Natural Resources Policy Consultative Group for Africa, Discussion Paper (Washington, D.C.: World Resources

and development will occur, especially if there is no corresponding development of an efficient pricing mechanism that provide an accurate measure of the relative value of resources.[12]

The critical link between environmental and economic sustainability depends ultimately on the establishment of a system of clearly defined property rights. Property rights exist in formal contracts as well as in implicit contracts. Land reform, particularly land reform driven by such issues as redistribution, may well fail to create a system of property rights in which an efficient allocation of environmental and natural resources may be determined. Ultimately, clearly defined property rights, like civil rights, depend on the institutions of civil society. With this perspective in mind, we now turn to economic considerations in sustainable development initiatives.

IV. Dimensions of Sustainable Resource Use

There are three dimensions critical to the economics of sustainable resource use. These are, respectively, the allocation of exhaustible resources, the role of environmental externalities, and the allocation of renewable resources. In each case we are looking at natural resources from which both useful energy and materials are extracted for use within the economy. All three dimensions are governed by the fundamental laws of thermodynamics, namely, the conversion of matter into energy from a finite stock of both in the universe, and the technical efficiency through which these conversions can be accomplished in both an engineering and economic sense, and the role of entropy in the allocation of resources over time.

In terms of economic theory on sustainable resource use, there are essentially two approaches: the classical economic tradition of Adam Smith and David Ricardo, and the neoclassical tradition of Alfred Marshall and the bulk of contemporary writers in economics. In this paper, we will use the neoclassical approach, taking into consideration the classical framework as it relates to issues of sustainable development initiatives. The reasons for the choice of a neoclassical framework will become clear as key aspects of sustainable development are examined.

A. Exhaustible Resource Use

Exhaustible resources such as minerals and fossil fuels are so classified since their ultimate stocks diminish with each conversion from one state to another over time. If the stock of these finite resources were known with precision, the economic problem would be under what conditions would society consume a fraction of those resources today and how much would be consumed by each subsequent generation. Long ago, Harold Hotelling (1931) devised a solution for the efficient allocation of exhaustible resources over time, namely, that if the market structure were a competitive one, extraction would proceed in such a fashion that the rental value, or user cost, would increase at the prevailing rate of interest, or discount.[13] If the rate of discount were to

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Institute, November 1996); and Aaron Zazueta, 1995, "Policy Hits the Ground: Participation, Equity and Environmental Decision-Making", (Washington, D.C.: World Resources Institute, 1994). See also, Dal O. Didia(1997), "Democracy, Political Instability, and Tropical Deforestation", *Global Environmental Change* (7):1, pp. 63-76; Gerald W. Scully (1988), "The Institutional Framework and Economic Development", *Journal of Political Economy* 96, pp. 652-662; and Derick W. Brinkerhoff with George Honadle, "Co-Managing Natural Resources in Africa: Implementing Policy and Institutional Changes in Five Countries", (Washington, D.C.: U.S. AID, Implementing Policy Change Project, IPC Monograph Number 4, October 1996).

[12] As an example, see R. Mendelsohn (1994), "Property Rights and Tropical Deforestation", *Oxford Economic Papers* 46, pp. 750-756;

[13] Harold Hotelling (1931), "The Economics of Exhaustible Resources", *Journal of Political Economy*, 39, 137-175. The literature on exhaustible resources is extensive. For a good survey, see Partha S. Dasgupta and Geoffrey M. Heal, *Economic Theory and Exhaustible Resources* (Cambridge: Cambridge University Press, 1979), and Anthony C. Fisher, *Resource and Environmental Economics* (Cambridge: Cambridge University Press, 1981). See also David W. Pearce and R. Kerry Turner, *Economics of Natural Resources and the Environment* (Baltimore: The Johns

increase, production would be shifted from the future to the present, and vice versa. In a zero discount environment, the amount of the exhaustible resource would be equi-proportional for each time period.

Hotelling's solution to the exhaustible resource problem was in terms of efficiency, not sustainability, even though there is an implicit relationship between the two in his model. If the time frame for the allocation of exhaustible resources is extended *ex ante*, then each generation would consume a proportionately smaller fraction of the total stock.[14] In the limit, as the number of time periods approaches infinity, the consumption of exhaustible resources in each time period would approach zero. As long as society adopts an infinite time horizon consistent with some underlying notion of sustainable resource use, then economic activity could no longer be sustained on the basis of exhaustible resource use. This was the implication put forth in a famous essay by William Stanley Jevons (1865) long ago in reference to England's then reliance on coal.[15] It was echoed in later writings, notably Frank Ramsey (1928), who advocated the use of a zero discount rate for exhaustible resources, thus extending their prospective extractive life for as long as possible.[16] Even if one adopts Ramsey's rule, the problem is that for an infinite time horizon, there would be virtually no consumption of the exhaustible resource in any given time period.

How does one get beyond the dilemma of exhaustible resource dependence? The neoclassical economic answer is that even if one adopts a finite horizon and any positive rate of discount, technological innovation brought through successive periods of economic growth would permit a continuous stream of resource substitution possibilities. In the medium term, this takes place in three basic ways. First, it occurs in the form of new discoveries that become economically feasible, thus adding to proven reserves. Second, it occurs as technological innovation improves the technical efficiency of exhaustible resource use, much as has been the case in the global economy following the energy crisis of the 1970's. Third, it occurs as eventual increases in the price of exhaustible resources induces a shift to renewable resource technologies.

Hopkins University Press, 1990), and Phillip G. LeBel, Energy *Economics and Technology* (Baltimore: The Johns Hopkins University Press, 1982).

[14] If one seeks to maximize utility from the consumption of an exhaustible resource, then the problem is to maximize the present value of utility derived from a consumption stream over a given time period. This can be expressed as: $Max\int U(c)e^{-\partial t}e^{nt}\,dt,$ where; U(c) is the utility associated with a per capita consumption flow of c, n is the rate of growth of population, δ is the rate of discount, subject to an income constraint of the form $C + \Delta K = F(K,S,L,t)$, where F = a returns to scale parameter in the economy's production function, K = the stock of capital; R = the flow of exhaustible natural resources, L = the stock of labor, and t = time. If society's production function is based on a Cobb-Douglas unitary elasticity of substitution form , then the underlying production function can be expressed explicitly as $C+ \Delta K = K^{\alpha 1}R^{\alpha 2}L^{\alpha 3}e^{\lambda t}$, where λ = the rate of technical progress. As to the dependence on exhaustible resources, the extractive flow at any one time is based on $\int R(t)dt=S$, where S = the stock of the economy's exhaustible resources. Stiglitz(1974) used this framework to suggest that if society's utility function is logarithmic (i.e., U = ln(c)), then the optimal extraction rate of exhaustible resources is equal to the pure rate of time discount minus the rate of population growth, i.e., $R/S = \delta - n$. If $\delta - n$ is 2 percent, then society should consume up to up to 2 percent of its remaining stocks of exhaustible resources each year. Stiglitz' formula for optimal utility is $R/S = ([\delta(1-\alpha 1)-v\lambda])/(1-\alpha l-a2v) - n$, where v - the elasticity of utility with respect to time. See, J.E. Stiglitz, "Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths," *Review of Economic Studies, Symposium on the Economics of Exhaustible Resources*, 1974, pp. 123-138.

[15] William Stanley Jevons, *The Coal Question*, ed. A.M. Flux (1865; reprint edition, New York: Augustus M. Kelley, 1965). Jevons, as others after him, did not foresee the rise of alternative technologies and resources, which in England's case was the shift from coal to petroleum and natural gas that occurred just a few decades after his essay was published.

[16] Frank P. Ramsey, "A Mathematical Theory of Saving", *Economic Journal* 38 (December 1928); 543-559.

Goeller and Weinberg (1976) provide a clear statement of the neoclassical notion of continuing substitutability as a basis for sustainable economic growth.[17] It should be noted that this position is embodied implicitly or explicitly in virtually all standard models of economic growth and development, as well as in the basic framework of policy initiatives in developing countries. It implies, among other things, that while sustainable growth and development require that one needs to take into account not just trends in current resource markets, but also that one devise suitable institutional mechanisms for research and development essential to creating opportunities for transitional paths to sustainable growth. In this sense, public support for continuing research into appropriate technologies is an important part of the framework for sustainable development initiatives, and whose social rates of return may be viewed as a function of prospective rates of increases in per capita incomes over time.

The neoclassical model is based on a number of important institutional considerations, among them efficient markets. When markets work imperfectly, as they do in many parts of the developing world, there is no clear basis for anticipating how resource substitutability is likely to occur. Much of the inefficiency of these markets derives in turn from imperfections in the definition of property rights, which is why institutional governance does matter.

We could limit our discussion to limitations in property rights as the critical constraint on sustainable growth and development. While there is certainly is value in focusing on incentives for efficient property rights, before we do so, we first need to look at how the presence of efficient property rights and markets will shape decisions on the environment and natural resource use in reference to sustainable development initiatives.

What does the neoclassical model of exhaustible resource use imply for economic development in a region such as Africa? We note first of all that some countries are exhaustible resource net exporters, while others are net importers. By itself, the international net position a country has in terms of exhaustible resources does not lead to any conclusion on sustainable growth possibilities. Where it does become relevant is in the context of global resource use, and how global exhaustible resource markets function provides important indicators as to whether one is in a phase of rising or falling relative scarcity, and whether changes in the real prices of these resources is around an exhaustible resource trend.

Figure 1 illustrates the issue of global resource scarcity in the case of a key exhaustible resource, crude oil. Measured in constant dollars, the real price of crude oil hit a peak at the end of the 1970's, much as did the prices of many other primary commodities in Africa. Since then, crude oil prices have been trending downward, along with the prices of other primary commodities. The question is whether current pricing behavior is indicative of a longer term downward trend or one that is about to reverse in a way consistent with the classical theory of long-term scarcity.

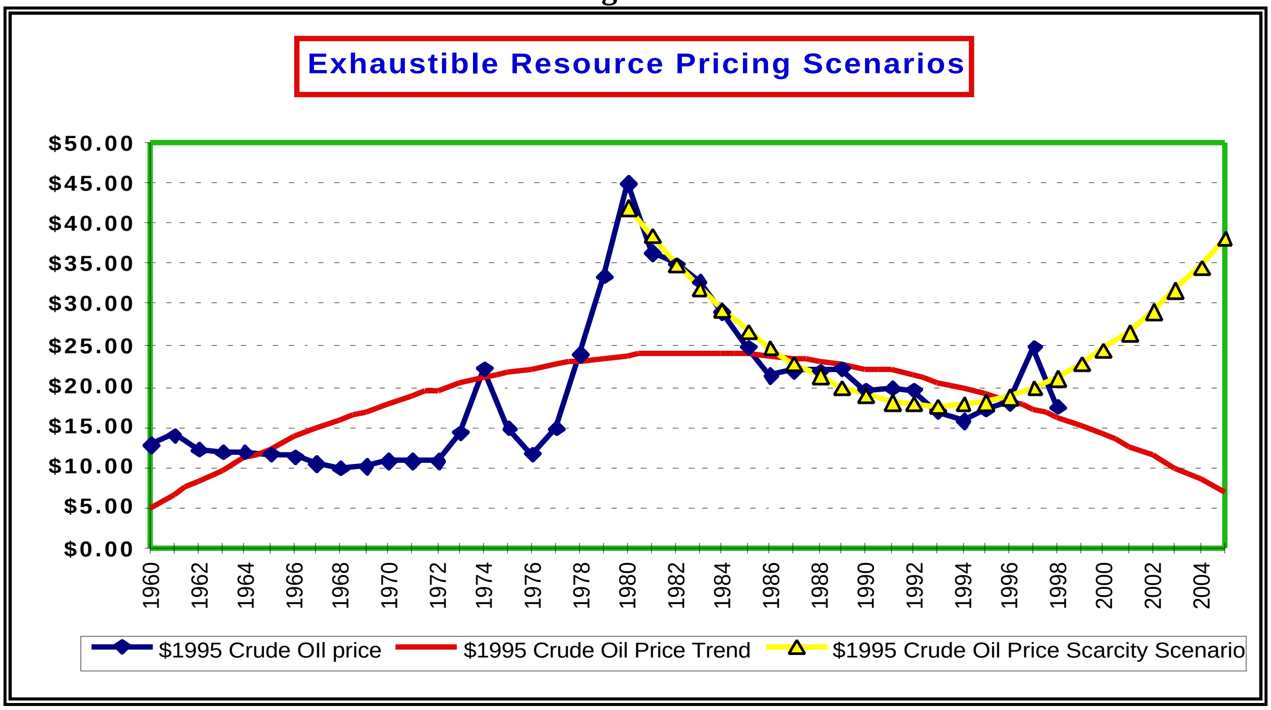
If we take a long-run trend based on data back as far as 1960, we would wind up with a downtrend price scenario. However, if we look at prices just since the peak in 1980, we may be witnessing an end to downward movement in crude oil prices and may be on the verge of a new upward trend that will become more obvious in the next few years. The classical economic model implies that long-run exhaustible resource scarcity may be setting in and under current conditions, per capita growth would not be sustainable under the present degree of dependence on oil and other fossil fuels.

If, on the other hand, we look at the determinants that gave rise to the downward trend in the 1980's, part of the shift was due to increases in end use energy efficiency, which in turn reflects continuing rates of innovation in the economy consistent with the neoclassical view. Because the neoclassical economic model does not rule out the eventual depletion of exhaustible resources and

[17] H.E. Goeller and A.M. Weinberg(1976), "The Age of Substitutability," *Science* 191: 683-689.

rising long-term prices, and because it bases sustainable growth choices on relative prices, it can accommodate the paradox of an apparent short-term upward trend in prices and a long-term downward trend in prices, given the role of technological change in the economy.

Figure 1



Source: World Bank data, using a 1992 energy price deflator recentered for 1995, and author's estimates.

What do crude oil price trends have to do with sustainable growth and development initiatives in Africa? First, Africa is a region that is both a producer and consumer of exhaustible resources. For countries that are net exporters of exhaustible resources, any upward trend in real primary commodity prices establishes a short-term basis for sustainable growth, much as was the case for many countries during the energy crisis of the 1970's. For other countries, However, given fluctuations in primary commodity prices, sustainable development will require that countries diversify their production in the face of commodity pricing risk, a strategy already being pursued in a number of countries.

Rising levels of per capita income imply increases in the consumption of exhaustible energy resources. Two outcomes derive from increases in per capita incomes. One is that they place continuing pressure on exhaustible energy resources, thus affecting the rate of depletion and the time frame for resource substitution choices to occur. The other outcome is additional environmental pollution. Before turning to the environment, let us link the analysis of exhaustible resources to sustainable growth and development initiatives.

A.1 Sustainable Development Initiatives with Exhaustible Resource Dependency

What steps are essential in managing exhaustible resource production and consumption consistent with sustainable growth and development. The first and most important step is that the pricing of exhaustible resources at all levels be based on their competitive social opportunity costs. This means that governments should refrain from adopting privileged or target markets either in terms of net subsidies or net taxes. The prices of exhaustible resources should reflect their value relative to all available competitive alternatives. As such, it means that emerging technologies must compete on the basis of the competitive scarcity value of exhaustible resources, thus promoting an efficient allocation of investment in alternative technologies as well as an efficient use of exhaustible resources.

If markets are efficient, they also will incorporate premia for the degree of uncertainty in the pricing of any resource. Creating and strengthening forward and option pricing for exhaustible resources is an important step in bringing about such efficiency. While some exhaustible resources already utilize these financial options, there are far too few such products available on local markets on which many end users depend. This is as important for net exporters of exhaustible resources in developing countries as it is for net importing countries, and certainly no less true for developing countries in Africa.[18]

The second essential step in managing exhaustible resources is to structure end-user markets in ways that promote greater flexibility. This means reducing barriers to entry and exit in exhaustible resource markets, not just at the international level, but also at the local level.[19] In Africa, as elsewhere, entrepreneurs have often developed inexpensive and competitive technologies for exhaustible resources, but often find that they can not succeed because certain markets are given privileged positions as either state-owned monopolies or as state-sanctioned private monopolies. Opening these markets to greater competition will serve not only the consumer but also the economy overall in helping to generate greater flexibility in the choice of technologies. If sustainable development initiatives to promote technological innovations in Africa have not done well, it is usually because the marketing conditions did not permit the emergence of commercially viable products that could satisfy end-user needs. Market-based reforms will accelerate the innovation of many of these products, thus increasing the economic efficiency in the use of exhaustible resources.

Third, creating greater market efficiency also means investing in human resources. Improving the knowledge and skills base is essential in the process of decentralization, particularly in reference to initiatives in support of democracy and governance in Africa. Strengthening civil society is an important step in this direction, particularly insofar as it also strengthens transferable

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[18] Commodity price risk management is not new to Africa. Commodity price stabilization boards have a long, and often disappointing, history, as tools for managing risk. Part of the failure of commodity price stabilization boards in the past as that they were poorly linked to a country's overall liability management options. Some evidence exists to show that there are offsetting effects between commodity price, quantity, import price, and exchange rate movements, but that they have been small. improving commodity risk management requires that external risks should be measured and managed with respect to net liabilities (which are external liabilities minus all external assets such as foreign exchange reserves), and net external liabilities have to managed on the basis of tradeoffs between the expected effective cost of a particular financial instrument and the uncertainty of its effective cost, where both cost and uncertainty have to be measured in relation to an economy's ability to pay. An economy's optimal external liability is thus divided between a speculative component and a hedging component. Claessens and Qian (1993) use a model of optimal liability portfolios for Sub-Saharan Africa and show that risk reductions using hedging instruments could reduce per capita dollar risk of up to 90 percent in comparison to standard practices. See Stijn Claessens and Ying Qian, "Financial Risk Management in Sub-Saharan Africa", in Stign Claessens and Ronald C. Duncan, editors, *Managing Commodity Price Risk in Developing Countries* (Washington, D.C.: The World Bank, 1993), pp. 330-357.

[19] Energy-conservation initiatives such as those devised under the CILSS (Comité Inter-étatique pour la Lutte contre la Séchéresse du Sahel) serve as a good example. When the energy crisis of the 1970's hit Sub-Saharan Africa, it was compounded by an expanded period of drought. CILSS was designed to mobilize resources for short-term relief as well as to devise long-term strategies to alleviate adverse conditions among affected populations. FEWS, the Famine Early Warning System, was designed to anticipate prospective harvesting shortfalls. However, in many instances, excessive government controls over farmer producer prices turns out to have had at least as much to do with famine conditions as any climatic variations. Major donor organizations have moved to dismantle such price controls, and local production has again begun to expand.

property rights that can be priced at their social opportunity cost.[20] At the same time, it should be emphasized that good governance by itself does not guarantee that sustainable growth and development can be achieved. What is critical is the establishment of legal systems that create transparency and enforceability of contracts, without which ownership of exhaustible resources will be incomplete and largely ineffectual.[21] Education and training that broadens the participation base, especially for women in Sub-Saharan Africa, is an important step in strengthening market institutions.[22]

Fourth, greater flexibility in the mix of exhaustible versus renewable resource technologies can only be accomplished through ongoing efforts in research and development. However, for research and development expenditures to be efficiently used, new technologies can succeed only if the pricing of existing resources is based on the competitive opportunity cost standard. In Africa, as elsewhere in the developing world, there are a number of technology research initiatives designed to increase the range of economic choices. Funding, which often comes from public national and international agencies, can be deployed productively only if the pricing of existing exhaustible resources is consistent with opportunity costs.[23]

Finally, performance indicators need to be developed that link funding of research and development to measured changes in per capita income, and thus to the ability of recipient countries to amortize the costs of resources made available through grants and loans. Until this occurs, the relatively few scarce resources that do go into alternative technologies are likely to be inefficiently used. Moreover, investment in research and development is likely to be far lower than optimal, and certainly far less than what is necessary for sustainable growth and development, largely because the presence of positive external benefits may not be captured by individual research and development, which is why public support of such expenditures becomes important.[24]

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[20]The institutions of civil society may be an essential pre-condition for the emergence of democratic society. This has been emphasized in Robert Barro, *Determinants of Economic Growth* (Cambridge: MIT Press, 1996); and more recently by Fareed Zakaria, "The Rise of Illiberal Democracy,"*Foreign Affairs* 76:6 (November/December 1997), pp. 22-43.

[21] There is a growing literature on the economics of property rights that has much relevance to the design of sustainable development initiatives. A useful reference is Yoram Barzel, *Economic Analysis of Property Rights*, second edition (New York: Cambridge University Press, 1997), while a more rigorous presentation of some theoretical issues can be found in Bernard Salanié, *The Economics of Contracts* (Cambridge: MIT Press, 1997), published originally in French as *Théorie des contracts* (Paris: Economica, 1994).

[22] In its review of sustainable bank initiatives, the World Bank places emphasis on improving the participation of women. While there is considerable emphasis on the role of education for women in enhancing environmental quality, there is little apparent linkage of such programs to the role of exhaustible resource management. See, Andrew Steer *et.al.*, *Advancing Sustainable Development: The World Bank and Agenda 21* (Washington, D.C.: The World Bank, Environentally Sustainable Development Studies and Monographs Series No. 19, 1997).

[23] Support for institution capacity building in Africa already represents an important part of international development initiatives. The Global Environmental Facility, the Consultative Group on International Agricultural Research, the Economic Development Institute, are but three examples of education and training programs supported by the World Bank. The problem that these programs pose for sustainable development initiatives is that they give current emphasis to environmental issues and have shifted away from a once prominent role placed on exhaustible energy and primary commodity markets, which may reflect a tendency to associate sustainable development only with envrionmental and renewable resource technologies even though exhaustible resources are very much part of any sustainable development strategy.

[24]In the abstract, the optimal level of research and development is that amount where the rate of return is just equal to the opportunity cost of capital. This may be obvious is the research is applied and has a near-market potential, but is less so in the case of pure research. Private market institutions may be better prepared to manage the former, while society at large may best choose the level of support for pure research, consistent with returns that can be linked to an economy's overall rate of increase in per capita income, a relationship that may only be approximated in

B. Thermodynamics, Externalities, and Sustainable Development

The laws of thermodynamics govern all resource conversions from one state to another.[25] Economists have often been accused of creating models, including the neoclassical one, by simply ignoring the these laws, even though they have given extensive consideration to environmental externalities which are a byproduct of them.[26] Thermodynamics tells us that energy can be neither created nor destroyed, only changed from state into another. Moreover, the technical efficiency of any energy conversion will be determined by the state of technology, which in turn will govern the ratio of useful to rejected energy. The greater is the ratio of the combustion temperature of any energy conversion process to the ambient temperature level, the higher will be the fraction of any energy transformation that is converted into useful energy. Over time, given the state of knowledge on the distribution of energy resources and technology, an economy would be expected to shift from low entropy forms to higher entropy forms, a process that is irreversible.

The relationship of thermodynamics to economics is that to the extent that markets incorporate efficient information on energy resources, then the statement that the economy will engage in a gradual shift from lower to higher entropy forms of energy will be true. For example, coal, oil, and natural gas are lower entropy energy forms than fuelwood, so one would expect an economy to rely first on the consumption of its exhaustible fossil fuels and then shift to renewable energy resources, be that fuelwood, or higher technology variants such as solar and wind technologies.

As simple and as appealing as the thermodynamic framework may seem, it is not consistent with much observed economic behavior. This is not to say that the laws of thermodynamics are wrong. The problem is that markets may be economically inefficient for a variety of reasons, among them being barriers to entry and exit, the fact that energy prices may not embody all of the costs and benefits in the consumption of a resource, as well as the state of technology.

When market prices do not embody all of the costs and benefits from the consumption of a resource, they result in external costs and benefits that affect parties other than buyers and sellers of a good. Environmental pollution arising from the purchase and operation of a road vehicle is a typical example of an external cost, while the lowered costs of farm exports arising the creation and operation of a road system represents an external benefit. The higher is the share of these costs and benefits as a percentage of the market value of a good, the less efficient will be the allocation of resources. Net external costs, unless otherwise corrected, result in excess production of a good while net external benefits will produce an under allocation of resources. Correcting for these externalities thus is an important step in improving the efficiency of markets, and plays a central role in shaping sustainable development initiatives.

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most instances, but nevertheless an important one to consider. See, for example, H. van Meijl, "Measuring the Impact and Indirect R&D on the Productivity Growth of Industries", *Economic Systems Research* 9(2), pp. 205-211; J. Greenwood; Z. Hercowitz, and P. Krusell, "Long-Run Implications of Investment-Specific Technological Change" *American Economic Review* (June 1997) 87(3), pp. 342-362.

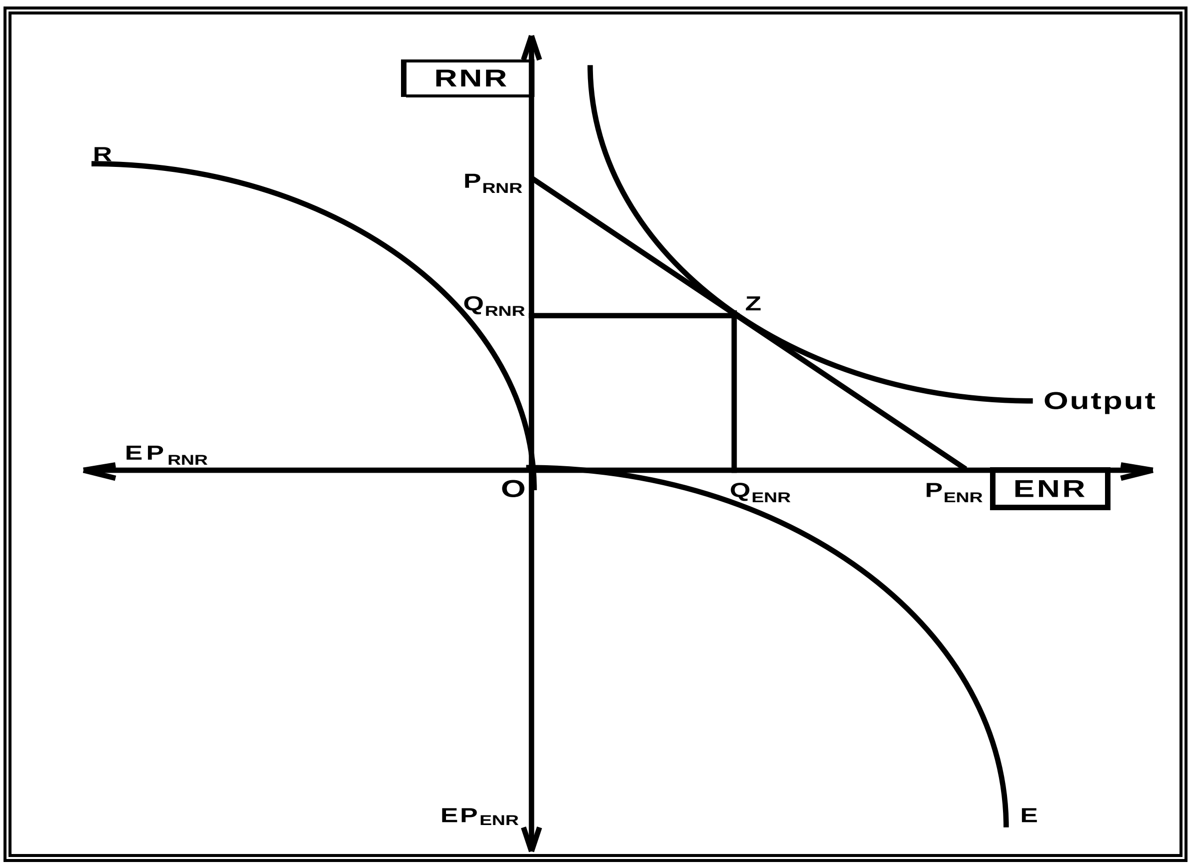
[25]See, for example, V. Kadambi and Manohar Prasad, *An Introduction to Energy Conversion* (New York: John Wiley and Sons, Halsted Press, 1976). Entropy, the tendency toward rising chaos with each successive conversion over time, has often served as a focal point of environmental criticisms of neoclassical economics. A good example is found in Nicholas Georgescu-Roegen, *The Entropy Law and the Economic Process* (Cambridge, Mass.: Harvard University Press, 1971), especially chapters 5 through 9. See also M. Faber, H. Niemes, D.G. Stephan, *Entropy, Environment and Resources: An Essay in Physico-Economics* (Heidelberg: Springer-Verlag, 1987); and Kenneth Boulding, "The economics of the coming spaceship Earth", in H. Jarrett, ed., *Environmental Quality in a Growing Economy* (Baltimore: The Johns Hopkins University Press, 1966); and Charles Perrings, *Economy and Environment* (Cambridge: Cambridge University Press, 1987).

[26]See, for example, "Externalities", in P.S. Dasgupta and G.M. Heal, *Economic Theory and Exhaustible Resources*, *op.cit*., pp. 39-94.

Let us look first at the problem of externalities in the context of exhaustible versus renewable energy resources, illustrated here in Figure 2. Consider that an economy produces any given level of output based on the state of technology and on relative prices. We show here just the role of natural resources in the process, denoted by Exhaustible Natural Resources (ENR), (e.g., oil, coal, natural gas, as well as non-energy minerals) and Renewable Natural Resources (RNR) (e.g., fuelwood, biomass materials, all agricultural outputs that also serve as inputs in a continuing process).

If a producer (which could include household production as well in this example) seeks to make economically efficient choices then one would select a mix of renewable and non-renewable resources that maximizes the level of output at the least possible cost, shown here as point Z. A producer may have a range of choices in terms of what inputs to use, and the degree of substitutability in these input choices is embodied in the convexity of the production set. What is critical is that a given level of income will determine the feasible range of choices, denoted here by a budget constraint P_{RNR}-P_{ENR}, whose slope is determined by the relative price of each input.

Figure 2
The Choice of Natural Resources in Production



If the level of income increases, then there will be a parallel shift outward in the budget constraint, while for any change in the relative price of either input, there will be a rotation of the constraint to reflect the new relative cost. Changes either in income or relative prices will have two kinds of effects. One is that they will affect the level of output that can be produced and the other is that they will affect the mix of resources used in production.

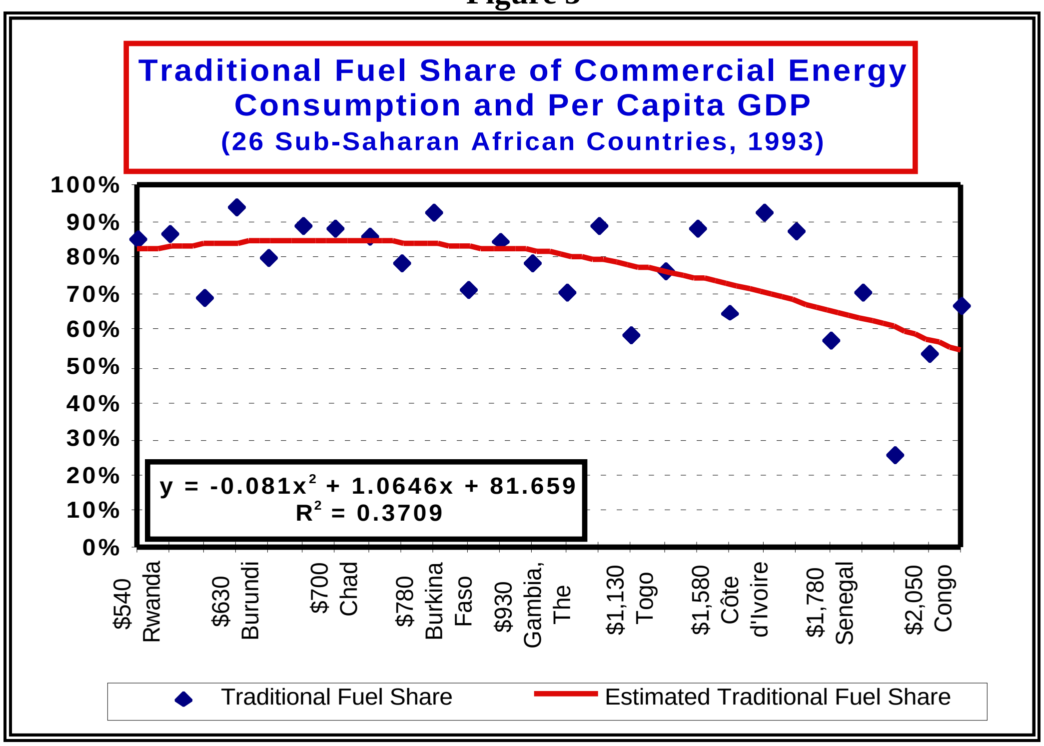
Let us now look at the presence of externalities in Figure 2. Because natural resources are used in production, there will be some consumption of these resources in the form of energy. We denote rejected energy, or environmental pollution, as embodied for each resource, along the respective curves, OE, and OR, and as measured respectively along the axes, EP_{ENR} and EP_{RNR}. The convexity of the functions OE and OR reflects both the underlying laws of thermodynamics as well as the state of technology at commercially available prices.

If the relative price of exhaustible resources increases, the first effect will be to reduce their consumption and to switch some consumption to renewable natural resources. This occurs as the budget constraint P_{RNR}-P_{ENR} rotates inward from P_{RNR} resulting in a new point of tangency of the budget constraint with some lower output function below the one already shown.

As this relative price change occurs, output will be lowered at least initially by some amount, as will the level of external cost arising from the reduced consumption of the exhaustible energy resource. In order to sustain output levels, producers now place increasing efforts to use renewable energy resources such as fuelwood. In the presence of efficient natural resource market pricing, there would be an increase in the price of renewable energy resources reflecting the increase in demand.

Because renewable natural resource markets are often incomplete, there simply may be a shift toward greater reliance on renewable energy resources, particularly fuelwood, without much directly observable effect on price. The result is accelerated consumption of the renewable energy resource, which at some point exceeds the biological reproductive potential of the resource. The renewable natural resource thus becomes the equivalent of an exhaustible energy resource. For Africa, this pattern is very much consistent with the accelerated deforestation and environmental degradation that occurred in conjunction with the energy crisis of the 1970's.

Figure 3



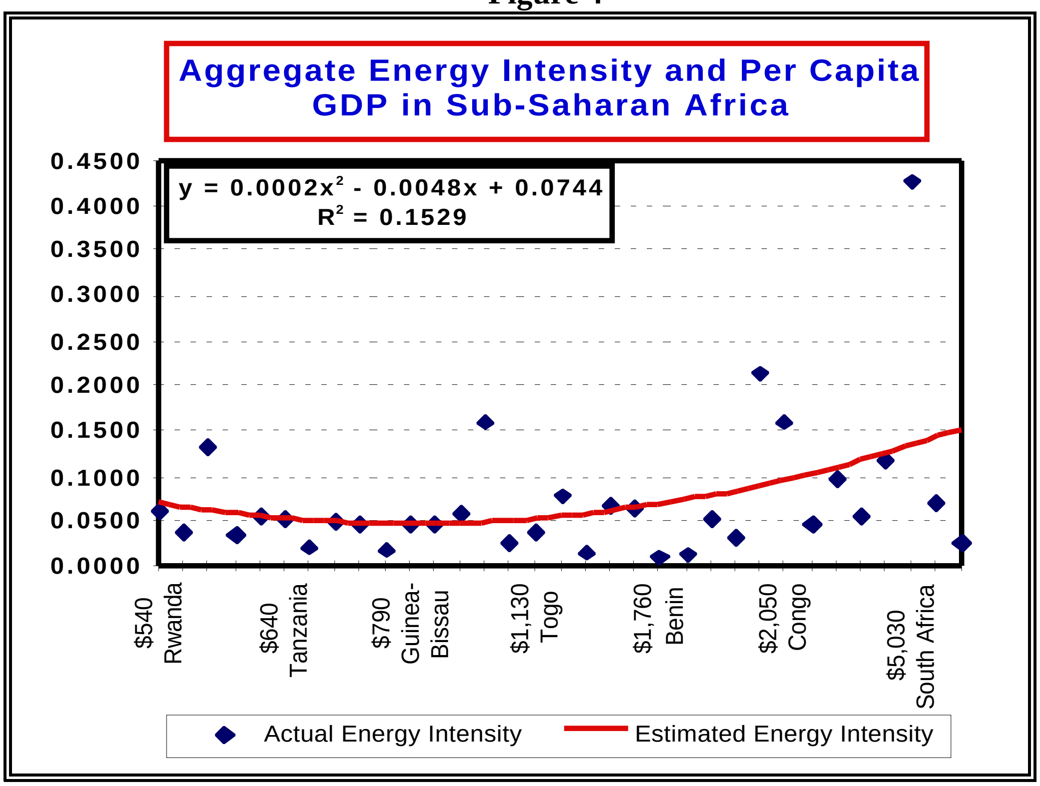
Source: The World Bank, *World Development Indicators*, 1997, and author's estimate.

What evidence do we have in terms of the relationship between per capita income and dependence on renewable natural resources in Africa? If we limit our measure of renewable natural resources to traditional fuels, we find that there is an inverse relationship between the degree of dependence on traditional fuels and per capita GDP, and which is shown here in Figure 3. This is consistent with the position already noted by Baldwin (1995) that economic growth is an important determinant of sustainable growth in that it would reduce the degree of reliance on traditional fuels as the level of income increases. This is not to say that traditional fuels can not play a role in sustainable growth and development, but that at current rates of consumption relative to production, the current pattern of economic growth for many developing countries is simply not sustainable.

Over a broader range of income, we would expect a u-shaped relationship between the degree of dependence of an economy on renewable natural resources and the level of per capita GDP. There would be, however, a qualitative difference in this dependence between the form of consumption of renewable natural resources at lower levels of per capita income than at high ones, reflecting differences in the state and distribution of technology. An important consequence of this expected relationship is that the thermodynamic efficiency in energy consumption also will differ across income levels. In terms of Figure 2, this means that technological advances can result in reduced environmental pollution for each level of production, and which would reflect changes in the convexity of the OE and OR curves, respectively, toward the ENR and RNR axes, though never achieving perfect congruence by virtue of the laws of thermodynamics.

Technological change in the consumption of exhaustible and renewable natural resources implies reduced environmental pollution. If there is reduced environmental pollution, then the percentage of any useful energy that is extracted from any energy conversion will be increased. At the same time, such technological improvement also means that there will be a smaller amount of energy consumed for each dollar equivalent level of production in the economy, which is measured as the degree of aggregate energy intensity.

Figure 4

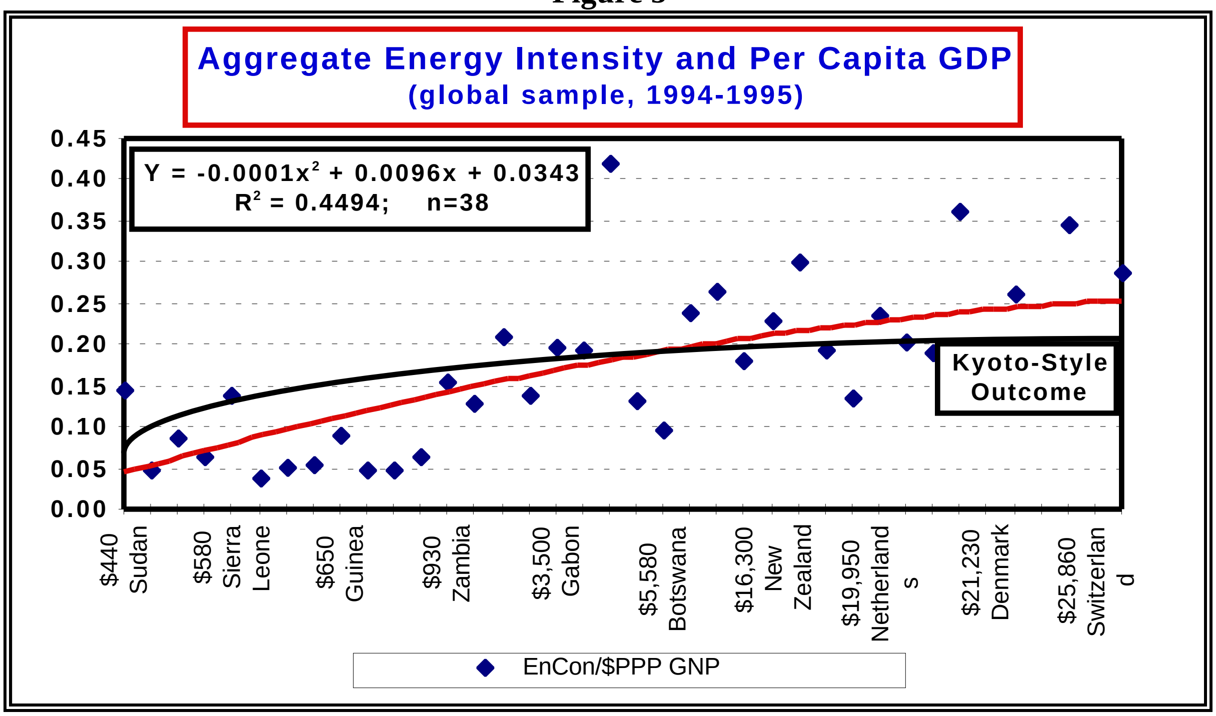


Source: The World Bank, *World Development Indicators*, 1997, and author's estimate.

What kind of resource transition is Africa like to experience as increases in per capita income take place? Figure 4 illustrates one likely pattern, based on a cross-section of 26 countries in 1994-1995. With increases in per capita income, as the transition from dependence on renewable natural resources to exhaustible natural resources occurs, there is likely to be an increase in aggregate energy intensity. This has both positive and negative consequences. One possible positive outcome is that a transition to exhaustible resources may relieve some of the pressure now bearing on the consumption of renewable natural resources. However, we are speaking here primarily in terms of a shift in the consumption of energy resources, and by no means is it a foregone conclusion that non-energy renewable natural resources will experience such a reduction in demand as long as other factors continue to be present.

On the negative side, increasing aggregate energy intensity arising from a shift to dependence on exhaustible natural resources implies rising environmental pollution, as the per capita level of vehicle and mechanical equipment consumption increases. Since developing countries have seen such a transition as a necessary step to a path of sustainable growth, the projected increase in environmental pollution has had much to do with negotiations on improved management of the global environment, most recently at the Kyoto summit in 1997.

Figure 5



Source: The World Bank, *World Development Indicators* (Washington, D.C.: 1997), and author estimates.

We can better understand the framework of the Kyoto summit in terms of another look at aggregate energy intensity and per capita GDP, based this time on a more globally representative sample. Figure 5 uses a sample of 38 countries to illustrate the pattern of energy intensity that is found when the level of income includes both developing and developed countries. Instead of an ever expanding rate of increase in aggregate energy intensity, the rate of increase tends to slow down as the level of income continues to rise, as is shown by the estimated relationship illustrated in red.

If countries continue to rely on present trends, the level of global environmental pollution is likely to rise, as several forecasting models have indicated in recent years.[27] Increases in carbon dioxide in the atmosphere, along with particulate emissions, may produce increases in global temperatures as a greenhouse effect takes place, with significant effects on global climate.[28] It is on this basis that the Kyoto summit produced an agreement that would allow developing countries greater latitude to make a transition from a dependence on traditional renewable natural resources to increased use of exhaustible natural resources. The rotated Kyoto-style curve embodies a compromise in which developed countries would continue to make efforts to reduce environmental pollution, even as they allow some greater margin of intensity among developing countries in a resource-base transition. It also embodies a commitment to a reduction in the level of global environmental emissions in which developing and developed countries can make use of pollution trading rights as a device to promote greater flexibility in achieving global objectives.

B.1 Economic Choices for Correcting Environmental Externalities

Externalities, be they negative or positive, reflect incomplete markets. As suggested in Figure 2, as long as market prices for resources do not reflect the social costs and benefits of their use, economies can send the wrong signals that lead to an inefficient use of resources. Since externalities have long been a pre-occupation among economists, it is worth noting how some proposed solutions may be applied to developing countries and what they imply for sustainable development initiatives now under way. It also should be emphasized that by virtue of the laws of thermodynamics, no alteration in the pricing of natural resources will eliminate completely the presence of environmental externalities. The worth of any proposal thus is whether any change produces a net improvement from the status quo, taking into account the social costs and benefits .

There are two basic approaches to managing natural resource markets in the presence of environmental externalities. One is to use government intervention in the form of regulation, taxes, and subsidies to correct for the incomplete valuation of natural resources using market prices alone. The other approach is to create markets for environmental pollution in the form of trading permits and set permit prices at levels that correspond to their environmental impact. While the Kyoto summit evoked the use of the latter, it is important to address the use of government intervention since this has traditionally served as the primary means of managing the level of environmental pollution.

Figure 6 illustrates the various ways in which both tradable permits and government intervention can be applied. Consider a market for an exhaustible natural resource such as petroleum. Market demand (D_{ENR}) and Supply (S_{ENR}) determine an initial equilibrium price ($P(1)_{ENR}$) and quantity (Q(1)). Corresponding to this market equilibrium also will be a level of environmental pollution ($EP(1)_{ENR}$). Because the market is incomplete, the economic consequence of this environmental pollution is unpriced directly in the petroleum equilibrium price. There are, however, environmental costs arising from the petroleum market, whose value will be determined indirectly in terms of reductions in the quality and health of the natural environment. The measurement of this external cost would be derived not from a PPP measure of per capita income, but in terms of human health indicators from a human development index, and, in terms of an index of environmental quality. The challenge, then, is to create institutional property rights such that adjusted market prices can make a more efficient allocation of resources.

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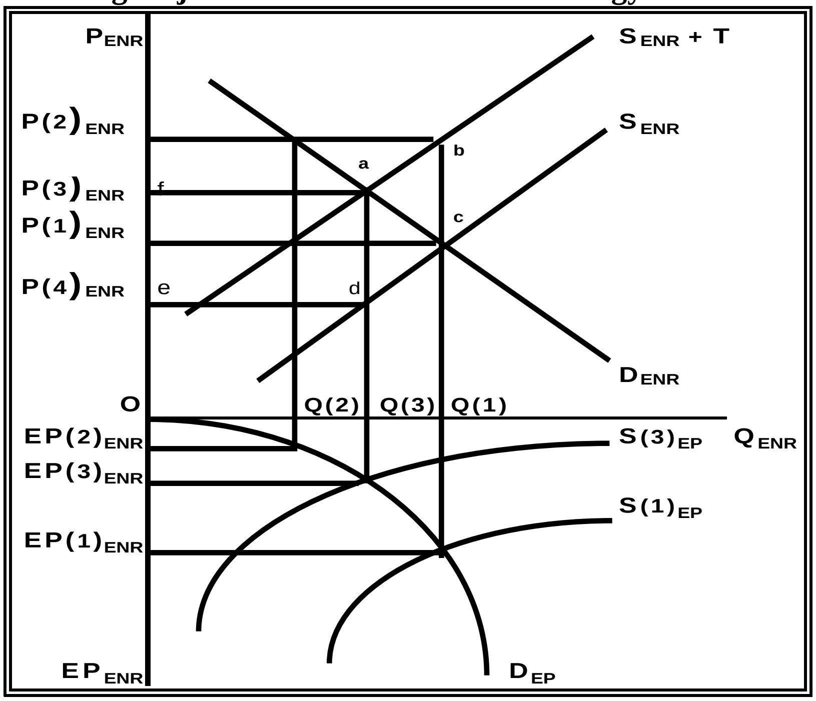
[27] See, for example, William A. Pizer, "Optimal Choice of Policy Instrument and Stringency under Uncertainty: The Case of Climate Change", (Washington, D.C.: Resources for the Future, working paper, December 1996); William Nordhaus, *Managing the Global Commons* (Cambridge: MIT Press, 1994); and William Cline, *The Economic of Global Warming* (Washington, D.C.: Institute of International Economics, 1992).

Figure 6
Pricing Adjustments for Exhaustible Energy Resources



The most basic approach to the reduction in environmental pollution is in terms of direct regulation. Governments that establish environmental action plans often set quantitative targets for the physical reduction of environmental pollution. In terms of Figure 6, a government might set a quantitative goal of reducing environmental pollution by some stipulated percentage from its current market level. Thus, **(**(EP(1)ENR-EP(3)ENR**)**/**(**EP(1)ENR**)** represents some targeted percentage reduction in environmental pollution. To achieve this reduction, government would establish environmental monitoring stations to track progress toward achieving the goal.

Governmental regulation is a form of taxation. In Figure 6, it is equivalent to a reduction in the supply curve from S_{ENR} to S_{ENR} + T. Faced with government standards regarding the level of environmental pollution, firms generally incorporate these costs in the pricing of the resources they use. Given that regulation also may reduce the profitability of operations, some firms may exit an industry as a result.

What economic value should be attached to the presence of and reduction in environmental pollution? We already have alluded to the impact of environmental pollution on human and natural resource indicators. In Figure 6, the economic value of these external costs is equivalent to the area, abc. The importance of this triangular valuation is that it also is a way of evaluating the costs and benefits of regulation. As long as the benefits of pollution reductions, abc, are greater than the administrative and compliance costs, then there is a nominal rational for their use. To say, however, that this calculus is used by governments in the setting of actual environmental standards would be presumptuous, which is why the application of regulation is such a contentious issue.

In lieu of direct regulation, governments can, of course, impose taxes to reduce the level of environmental pollution. As already noted in Figure 6, the leftward shift in the industry supply curve may be thought of as the effect of taxation on the determination of market equilibrium. However, the application of a tax will differ in that government now derives revenue from its environmental policy controls. The unit tax level will be equivalent to the segment, ad, (or $P(3)_{ENR}$-$P(4)_{ENR}$), which when multiplied by the post-tax market equilibrium generates tax revenues equal to, adef.

How should an environmental tax be evaluated? One is in terms of effectiveness, i.e., whether the tax achieves the target percentage reduction in environmental pollution. Another approach is to evaluate the efficiency of the tax. Here the appropriate measure is the deadweight social welfare loss arising from the tax, as measured by the triangle, acd, as a percentage of total tax revenues raised, adef. If the excess burden tax ratio of acd to adef exceeds some threshold level, then the tax may still be effective but it is not an efficient method of achieving the desired environmental standard.

The third variant of government intervention is in terms of environmental subsidies. Here, government may impose taxes elsewhere in the economy and use the proceeds to foster environmentally more benign technologies. In this case, the price $P(1)_{ENR}$ and quantity Q(3) may still be the level of natural resource use generated in the market, but subsidies have enabled the adoption of a production technology that rotates the D_{EP} curve closer to the x axis. Thus, for any given level of natural resource demand and supply there will be a correspondingly lower level of environmental pollution and the gap between the private and social market price will be correspondingly smaller.

Evaluation of an environmental technology subsidy should proceed with several considerations in mind. One might logically ask why should public resources be used to reduce the environmental pollution arising from private market transactions. The simple answer is that society derives benefits from their reduction and so it is in their collective self-interest to undertake the costs of abatement. The problem with this approach is that it seems to absolve a polluting firm from any responsibility for the environmental damage that it is causing. The flip side of this proposition is that as long as society has a demand for the goods whose production requires the creation of environmental pollution, then there is a basis for society to participate in the costs of its reduction.

What about tradable pollution permits? This approach takes as a point of departure that government regulation, taxes, and subsidies may be inefficient to implement and that a principal reason why this be the case is that there is no visible market valuation of the environmental pollution process. Tradable permits are based on the notion that markets for pollution rights can be established which would allocate pollution to those firms and industries that have the highest market value of their goods and services. The price of these permits would be determined on the basis of the level of environmental pollution that could be absorbed by the environment with minimal damage. The greater the damage from a given unit of pollution, the higher would be the permit price, recognizing that there is no positive pollution permit price that would equate to a level of zero pollution. This is, in effect, the solution embraced in the Kyoto summit, and it will have implications for firms, industries, and countries in Africa as the new system evolves.

B.2 Implications of Environmental Externalities for Sustainable Development Initiatives in Africa

With some exceptions, countries in Africa suffer less from the environmental pollution arising from the consumption of exhaustible natural resources than they do from the environmental costs of a declining renewable natural resource base. This is not to dismiss the importance of exhaustible natural resource environmental pollution. Indeed, to the extent that African countries succeed in achieving the kind of energy transition already noted, then there will be a corresponding greater emphasis on the choice of alternative policies along the lines suggested here.

Beyond the issue of relative dependence on renewable versus exhaustible natural resources, African countries do confront the question of establishing more efficient pricing for natural resource markets. Regulation will undoubtedly be used as a tool, if for no other reason than the relatively simplicity of its application. However, as investment in human resources expands, it also is important to consider the fostering of improved natural resource markets, including the use of environmental pollution trading permits. To do so is not to embrace the expansion of environmental pollution, but rather to consider ways in which efficient valuations of natural resource markets may be made.

Thirdly, one important step toward improved environmental management in Africa is the development of markets for product recycling. Some markets for product recycling have long existed in Africa, as in the case of steel plating used in agricultural tools, household kerosene lamps, and a variety of other products. To the extent that recycling markets can flourish, they reduce the costs of environmental restoration, and thus the need for environmental taxes or other forms of public sector intervention. For recycling market to expand, however, governments will need to develop enabling policies that enhance rather than reduce the level of market competition.

Table 1
Aggregate Energy Intensity and Environmental Emissions in Sub-Saharan Africa

	PPP GNP/P.C. 1995	Energy Intensity EnCon/$PPP GNP	Kg of CO2 Emissions per $ of GDP,1992
Sudan	$440	0.15	0.20
Ethiopia	$450	0.05	0.40
Zaire	$490	0.09	0.70
Rwanda	$540	0.06	0.20
Mali	$550	0.04	0.20
Sierra Leone	$580	0.14	0.60
Burundi	$630	0.04	0.10
Madagascar	$640	0.05	0.30
Tanzania	$640	0.05	0.50
Guinea	$650	0.09	0.40
Chad	$700	0.02	0.20
Malawi	$750	0.05	0.40
Niger	$750	0.05	0.50
Burkina Faso	$780	0.02	0.20
Guinea-Bissau	$790	0.05	1.00
Mozambique	$810	0.05	0.60
Gambia, The	$930	0.06	0.60
Zambia	$930	0.15	1.00
CAR	$1,070	0.03	0.20
Togo	$1,130	0.04	0.60
Nigeria	$1,220	0.13	2.60
Angola	$1,310	0.06	0.60
Kenya	$1,380	0.08	0.60
Uganda	$1,470	0.02	0.10
Mauritania	$1,540	0.07	2.90
Côte d'Ivoire	$1,580	0.06	0.60
Benin	$1,760	0.01	0.30
Senegal	$1,780	0.06	0.60
Ghana	$1,990	0.05	0.60
Zimbabwe	$2,030	0.21	0.70
Congo	$2,050	0.14	1.60
Cameroon	$2,110	0.05	0.20
Gabon	$3,500	0.20	1.30
Namibia	$4,150	0.20	1.10
South Africa	$5,030	0.42	3.50
Botswana	$5,580	0.10	0.90
Mauritius	$13,210	0.03	0.50

Source: The World Bank, *World Development Indicators 1997*.

Table 1 provides a summary profile of aggregate energy intensity and environmental emissions in Sub-Saharan Africa. Tests on these data using an energy price variable show that energy intensity declines in response to an increase in the price of energy, much as one would expect.[29] In turn, because energy intensity is directly related to CO^2 emissions intensity, maintaining a relatively high energy price is an effective way to achieve lower CO^2 emissions.[30] However, as noted in reference to Figure 2, the higher the price of commercial energy, the greater is likely to be the shift to accelerated consumption of traditional renewable energy resources. To the extent that this shift accelerates the consumption of traditional renewable energy resources beyond their natural replacement rate, then reductions in the intensity of environmental emissions are likely to reduce an economy's natural capital stock.

C. Renewable Natural Resources

The third element in any sustainable development initiatives is the management of renewable natural resources. Renewable natural resources can be produced in a state of nature, or in the framework of a market economy. For those renewable natural resources that are produced in an economic framework, property rights become as important as they are in the case of exhaustible natural resources. Let us look first at the common property resource problem and then examine the specifics of renewable natural resources in the context of sustainable development initiatives.

C.1 The Common Property Resource Problem

As in the case of environmental pollution, common property resources pose valuation problems that also can lead to a mis-allocation of resources. For example, markets may not exist for common property resources because property rights have not been clearly determined. A common property resource may be managed by a community, as often is the case in many African countries, but prices are not applied in a visible market sense. One may, for example, acquire simple usufruct rights on the basis of being a member of the community. In the absence of a pricing mechanism, as population increases, the community may simply assign smaller quotas to its members as a form of economic triage. Such efforts to provide community equity may bear no resemblance to the price that a resource needs to command if it is to be replenished at rates that provide for steady-state stocks.

Figure 6 also can be used to illustrate the common property resource problem. Instead of environmental pollution being portrayed in the fourth quadrant, we can think of D_{EP} as representing the stock of common property natural resources. Each time a market transaction occurs, or what is equivalent, the right to harvest is decided by a community, the supply of the natural resource will be affected. If the harvesting rate exceeds the production rate, then this is equivalent to a leftward shift in the supply curve and a corresponding lower level of common property natural resource stocks, as in the movement from $EP(1)_{ENR}$ to $EP(3)_{ENR}$. If, on the other hand, a community devises

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[29] The rate of change in energy intensity was estimated as a function of the rate of change in the price of energy and the rate of change in per capita GDP. The resulting equation is:

Ln(Energy Intensity) = -.014654 - 3.959316 Ln(GasolinePrice) - 0.0021 Ln(Per Capita GDP)
(-170.41)t (-.368358)t

Adjusted R^2 = .99; DW = 1.95; F=15354. Energy prices thus overwhelm the role of rising per capita income, which is not statistically significant in this equation.

[30] Energy pollution intensity, as measured by the ratio of CO^2 emissions per dollar equivalent of GDP, are a function of energy intensity, which also can be explained in terms of per capita GDP and the relative price of energy. Estimating the rate of change in pollution emissions per dollar of GDP as a function of the rate of change in per capita GDP and the rate of change in the price of energy, we find the following:

Ln (CO^2/GDP) = -.97729 + .31026 Ln(PC GDP) -2.745 Ln(Gasoline Price)
(2.413)t (5.241)t

Adjusted R^2 = .5234; DW = 2.308; F = 20.772. Although rising per capita income tends to increase the rate of emissions intensity, it is offset by the rate of change in energy prices.

a way to increase the rate of common property natural resource stock growth relative to demand, there will be a net increase in the supply curve to the right and stocks will increase accordingly. This can occur from improved management of existing resources or through biotechnology advances in the production of natural resources.

In both cases, the valuation problem is similar. Market prices tend to undervalue the common property resource, leading to greater rates of harvesting than is sustainable. Creating systems of transferable property rights is an important step in bringing market valuations closer to sustainable valuation levels. Establishing transferable property rights requires, however, some mechanism for placing a value on the assets in the common property resource. It may be, for example, that society is less interested in extracting the physical resources from the environment than from preserving it in a state of nature, much as is illustrated by efforts to preserve wildlife diversity in many parts of Africa.

Establishing property rights for a state of nature requires that one devise a method of contingent valuation.[31] This is a well established method in economics and it involves essentially the determination of the willingness of individuals to pay for the right to enjoy the environment without any extraction of the natural assets that are found within it. Eco-tourism represents a market for such initiatives and creates a market-based solution to the valuation of common property resources.[32] This is just as valid for wild animals as it is for marine sanctuaries designed to protect endangered species. The pricing of these resources should be set at the level sufficient to deter consumption of the resources beyond some steady-state rate in the growth of natural stocks.

C.2 Renewable Natural Resources and Sustainable Economic Growth in Africa

While there has been fairly widespread agreement on the use of economic benchmarks for international development initiatives, there has been less consensus on the meaning and measurement of natural capital, and thus the definition of sustainable natural resource use.[33] The simple reason why this occurs is that changes in natural capital may not be reflected in market prices, and thus in national income accounts that are used to measure changes in per capita income. The challenge of sustainable growth thus turns very much on the extent to which we fashion institutions to generate efficient pricing of natural resources.

Independent of human action, renewable natural resources follow growth cycles that are shaped by the broader environment. They do so singly, and in complex interactions in nature, as in predator-prey relationships among animal species. Some of these dynamics are yet to be discovered, which forms the primary case for a commitment to biodiversity.[34]

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[31] Contingent Valuation is the setting of prices on the basis of the willingness to pay for access to a resource to be preserved in its natural state or improved, or equivalently, the minimum they would be willing to accept for a decline in environmental quality if a market existed for the good. For a critical review, see Anil Markandya, "The Value of the Environment: A State of the Art Survey", in Anil Markandya and Julie Richardson, *Environmental Economics: A Reader.* (New York: St. Martin's Press, 1992), pp. 142-166. Closely related to contingent valuation is the notion of option prices and existence values for wildlife resources. See in the same volume, David S. Brookshire, Larry S. Eubanks and Alan Randall, "Estimating Option Prices and Existence Values for Wildlife Resources", pp. 112-128. Option prices become particularly critical in the case of wildlife species. See, for example, Curtis H. Freese, editor, *Harvesting Wild Species: Implications for Biodiversity Conservation* (Baltimore: The Johns Hopkins University Press, 1997).

[32] See, for example, Erin O. Sills, "Contingent Valuation of a Forest Ecosystem: Evidence from Indonesia", working paper, ASSA annual meeting, Chicago, Illinois, January 4, 1998.

[33] One approach is to developed an environmentally adjusted system of national income accounts. See, for example, United Nations Statistical Office, *SNA Draft Handbook for Integrated Environmental and Economic Accounting* (New York: United Nations, 1992). While there will be continuing efforts to develop such "green" macro-accounting systems, we will focus here on the micro-foundations of sustainable growth initiatives.

[34] Op. cit., Edward O. Wilson, *The Diversity of Life*.

Let us look at some general measures of sustainable growth in Africa. Table 2 lists growth rates of key natural resource and economic growth indicators for 37 countries in Sub-Saharan Africa. Countries that have positive rates of growth in PPP GDP per capita can be thought of as economically sustainable(column E). However, given that many of these countries have relatively low rates of physical capital formation, because they rely more on the consumption of natural capital resources, we need an alternative definition of sustainable growth.

Table 2
Sustainable Growth Natural Capital Indicators in Sub-Saharan Africa

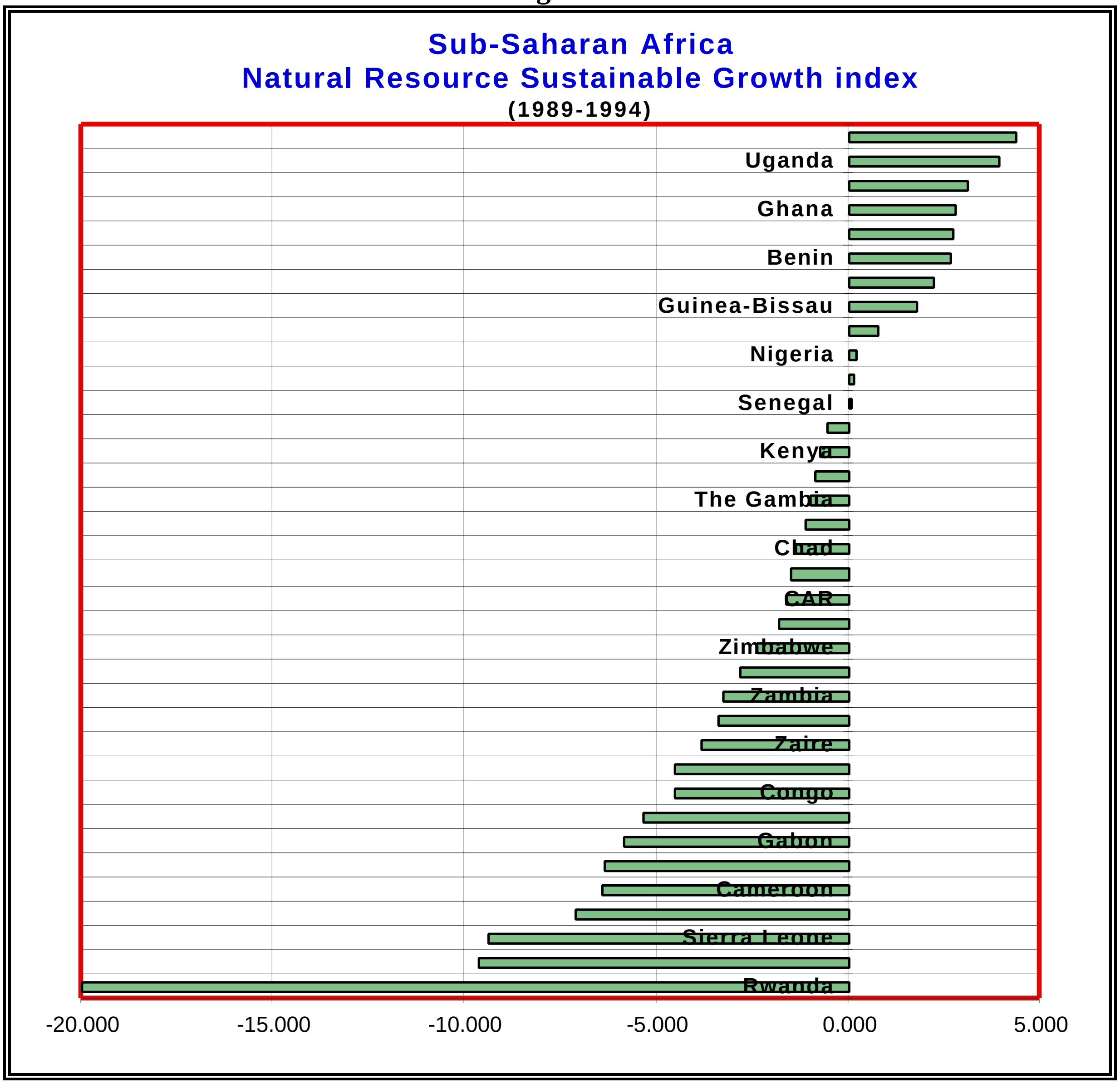
	A	B	C	D	E	F	G	H
	GDP Annual Growth Rate 1990-95	Population Growth Rate 1995-2010	Annual Rate of Afforestation 1980-90	Agricultural Productivity Annual Growth Rate	Natural Capital Productivity Growth Index(*) NCPGI=(a)*C+(1-a)*D	Per Capita Economic Growth Index PCEGI=A-B	Per Capita Natural Capital Productivity Index PCNCPI=E-D	Per Capita Sustainable Growth Index PCSGI=F+G
Rwanda	-12.80	3.50	-0.20	-0.1625	-0.1719	-16.3000	-3.6719	-19.9719
Angola	-4.10	2.80	-0.70	0.3323	0.0742	-6.9000	-2.7258	-9.6258
Sierra Leone	-4.20	2.70	-0.60	0.4775	0.2081	-6.9000	-2.4919	-9.3919
Togo	-3.40	2.70	-1.50	2.7400	1.6800	-6.1000	-1.0200	-7.1200
Cameroon	-1.80	2.90	-0.60	1.7708	1.1781	-4.7000	-1.7219	-6.4219
Burundi	-2.30	2.50	-0.60	1.4103	0.9077	-4.8000	-1.5923	-6.3923
Gabon	-2.50	2.30	-0.60	1.8294	1.2221	-4.8000	-1.0779	-5.8779
Niger	0.50	3.20	-0.40	0.8533	0.5399	-2.7000	-2.6601	-5.3601
Congo	-0.60	2.60	-0.20	1.7451	1.2588	-3.2000	-1.3412	-4.5412
Madagascar	0.10	2.80	-0.80	1.5798	0.9849	-2.7000	-1.8151	-4.5151
Zaire	-0.30	2.50	-0.60	2.1202	1.4402	-2.8000	-1.0598	-3.8598
South Africa	0.60	1.90	0.80	-0.5262	-0.1946	-1.3000	-2.0946	-3.3946
Zambia	-0.20	2.10	-1.10	1.8427	1.1070	-2.3000	-0.9930	-3.2930
Malawi	0.70	2.40	-1.40	2.1228	1.2421	-1.7000	-1.1579	-2.8579
Zimbabwe	1.00	1.60	-0.70	0.0000	-0.1750	-0.6000	-1.7750	-2.3750
Côte d'Ivoire	0.70	2.20	-1.00	2.8358	1.8769	-1.5000	-0.3231	-1.8231
CAR	1.00	2.00	-0.40	1.9364	1.3523	-1.0000	-0.6477	-1.6477
Mali	2.50	3.00	-0.80	2.9278	1.9959	-0.5000	-1.0041	-1.5041
Chad	1.90	2.40	-0.70	2.2804	1.5353	-0.5000	-0.8647	-1.3647
Namibia	3.80	2.30	-0.30	-0.3040	-0.3030	1.5000	-2.6030	-1.1030
The Gambia	1.60	2.10	-0.80	2.4063	1.6047	-0.5000	-0.4953	-0.9953
Tanzania	3.20	2.60	-1.20	1.8681	1.1011	0.6000	-1.4989	-0.8989
Kenya	1.40	2.20	-0.60	3.1830	2.2372	-0.8000	0.0372	-0.7628
Guinea	3.80	2.80	-1.20	2.0291	1.2219	1.0000	-1.5781	-0.5781
Senegal	1.90	2.50	-0.70	4.4889	3.1917	-0.6000	0.6917	0.0917
Mauritania	4.00	2.30	0.00	0.9533	0.7150	1.7000	-1.5850	0.1150
Nigeria	1.60	2.60	-0.70	5.2809	3.7857	-1.0000	1.1857	0.1857
Burkina Faso	2.60	2.70	-0.70	4.9747	3.5560	-0.1000	0.8560	0.7560
Guinea-Bissau	3.50	2.10	-0.80	3.5461	2.4595	1.4000	0.3595	1.7595
Mozambique	7.10	2.40	-0.80	0.1862	-0.0603	4.7000	-2.4603	2.2397
Benin	4.10	2.60	-1.30	5.4676	3.7757	1.5000	1.1757	2.6757
Botswana	4.20	1.70	-0.50	2.7712	1.9534	2.5000	0.2534	2.7534
Ghana	4.30	2.40	-1.40	4.8696	3.3022	1.9000	0.9022	2.8022
Sudan	6.80	2.20	-1.10	1.3106	0.7079	4.6000	-1.4921	3.1079
Uganda	6.60	2.60	-1.00	3.6840	2.5130	4.0000	-0.0870	3.9130
Mauritius	4.90	1.00	-0.20	2.0659	1.4994	3.9000	0.4994	4.3994
Ethiopia	2.40	2.80	-0.30	n/a	n/a	-0.4000	n/a	n/a

Source: The World Bank, *World Development Indicators 1997*.

(*) Natural capital productivity growth index weights: 0.25 for forestry productivity, 0.75 for agricultural productivity. Weights should be based on the economic value of the capitalized asset. Since such a measure is not readily available, these weights should be considered as illustrative.

We will consider here that a country's agricultural productivity, along with its rate of affforestation (with deforestation accounted for by negative values), provide us with a proxy for the rate of change in natural capital. The natural capital productivity index is the weighted average of the productivity indices of agricultural and forestry, where weights can be derived from the economic value of these resources in national income and product accounts. In turn, the natural capital productivity index can be measured on a per capita basis (defined here as column G, which is column E minus column B). Finally, we define our natural resource sustainable growth index as the sum of the PPP per capita GDP real growth rate plus the per capita change in natural capital productivity, or PCSGI, as shown in column H. We can then take the PCSGI and rank order the sample of countries in terms of their sustainable growth performance, as is shown in Figure 7.

Figure 7



Source: Table I, as derived from the World Bank, *World Development Indicators, 1997*.

Our index is far from perfect and is meant only to serve as a first order approximation. For one consideration, the time series of the variables used here are not identical. Second, as should be obvious, there are many elements of an economy's natural capital stocks that are not included here - fisheries and wildlife, for example. Third, we have not taken into account any measure of an economy's physical capital stock formation. Fourth, because our sustainable growth measure incorporates four separate variables, the rate of sustainable growth and the corresponding rank ordering will change from year to year, depending on changes in the determinants of each of these variables. Fifth, deforestation rates should be measured in terms of biomass rather than in terms of forest area. Finally, even with a consistent rank ordering over time, the index is far too aggregated to be able to devise strategic development initiatives.

With all of the above caveats, how meaningful is our measure of natural resource sustainable growth? Herman Daly (1989) has argued that there are two ways to define sustainable growth, namely, strong and weak sustainability.[35] Strong sustainability would require that the ratio of natural capital stocks to per capita income remain constant or increasing over time, while weak sustainability would require that the combined stock of natural and physical capital relative to per capita income be constant or increasing over time.

There are several difficulties with strong sustainability. In the extreme, it would require that population increase no faster than the slowest growing species of plant or animal life, regardless of differential rates of biological life cycles and independent of any human intervention. However, what makes this measure equally problematic is that it does not take into consideration the costs and benefits of these resources, and which is why we have such contentious debates such as the value of spotted owls in a commercial forest, or the snail darter along a commercial riverway. In short, absent any economic valuation, we risk engaging in a Noah syndrome, which is to inventory all species with a view toward their conservation independent of any other criteria. In short, we need to measure the cost of the boat as we load up the species.

Daly recognizes that strong sustainability may not be readily achievable, but argues that policies in developing countries do not even meet the test of weak sustainability in many cases. He thus argues that weak sustainability should serve as a benchmark floor in devising sustainable growth alternatives. We will keep both concepts in mind as we look to the economics of sustainable growth.

Where, then, can we move the discussion on natural resource use such that we can establish some economic comparability consistent with our underlying definitions of sustainable growth and development? Several steps are needed to answer this question. First is to define sustainable use in terms of the underlying physical dynamics of natural resources. Second is to define market prices consistent with the dynamics of supply and a corresponding level of demand. Third is to devise incentives to provide economic values to the natural resource base and to determine the limit values consistent with some underlying notion of preservation and expansion of a society's stock of natural capital. Finally, we need to integrate these steps with institutional and policy initiatives to establish a consistent framework for sustainable economic growth. Let us consider each in turn.

C.3 Biophysical Sustainability

From a purely environmental perspective, sustainable resource use means that the extraction rate of a renewable natural resource does not exceed the replacement rate. The standard interpretation in environmental resource accounting is that the harvesting of a renewable natural resource cannot exceed the maximum sustainable yield level. Any rate above this rate eventually will deplete the renewable natural resource to zero. Any positive rate of harvesting less than the maximum sustainable yield will generate an eventual steady-state production path whose value will depend on whether harvesting begins before the maximum sustainable yield rate or after.

Figure 8 illustrates the natural growth rate of a given renewable natural resource. Growth occurs initially at an increasing rate, followed by a decreasing rate, and eventually at a zero rate. The carrying capacity of the natural environment is the upper limit of growth, whose rate of change is zero. While there are several variants of natural resource growth curves, we will use the logit curve as a first order approximation.[36]

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[35] *Op.cit*., Daly(1989), pp. 71-72.

[36] The curve was first put forth by P. Verhulst in "Notice sur la loi que la population suit dans son accroissement," *Correspondance Mathématique et Physique* 10 (1838), pp. 113-121. See also, Colin W. Clark, *Mathematical Bioeconomics*, second edition. (New York: John Wiley and Sons, 1990); and D'Arcy Wentworth Thompson, *On Growth and Form,* revised edition (New York: Dover Reprint edition, 1992); For an empirical approximation, see Judd Hammack and Gardner Mallard Brown, Jr., *Waterfowl and Wetlands: Toward Bioeconomic Analysis*. (Washington, D.C.: Resources for the Future 1974). Figure 1 is based on a logistical growth equation of the form:

Figure 8

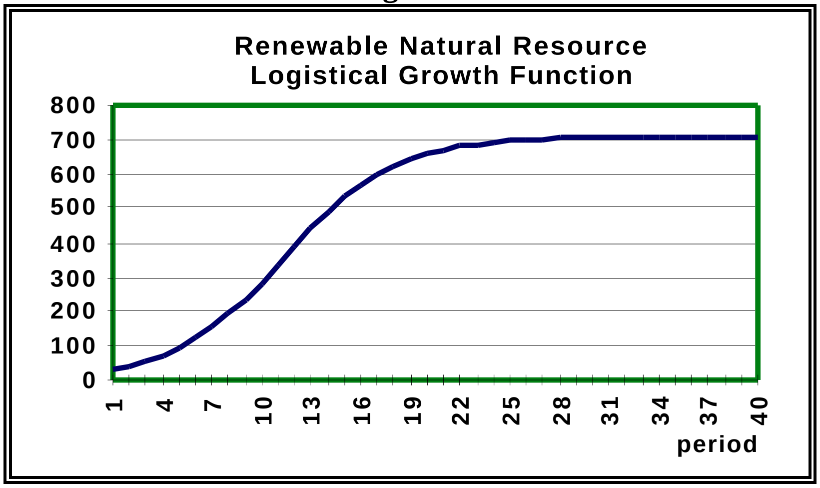

Figure 9

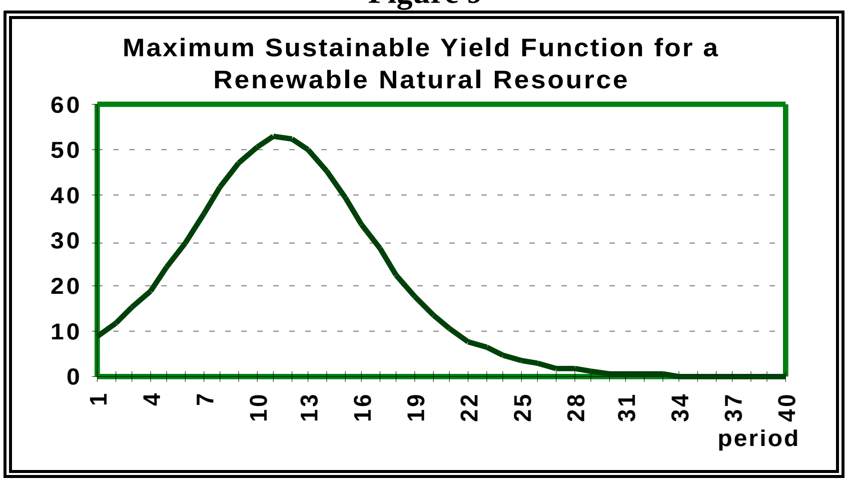

Figure 9 illustrates the increase in growth, measured as some unit of biomass, as a function of time for a single species. It turns out that the maximum sustainable yield occurs where the stock of

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$X = \frac{K}{1 + ce^{-rt}}$, *where :*

X = *production at time t,*

K = *the carrying capacity of the species in the environment,*

c = *a constant term defined by* $(K - x_o)/x_o$, *where* x_o = *an initial output level,*

e = *the base of natural logarithms ,or 2.71828,*

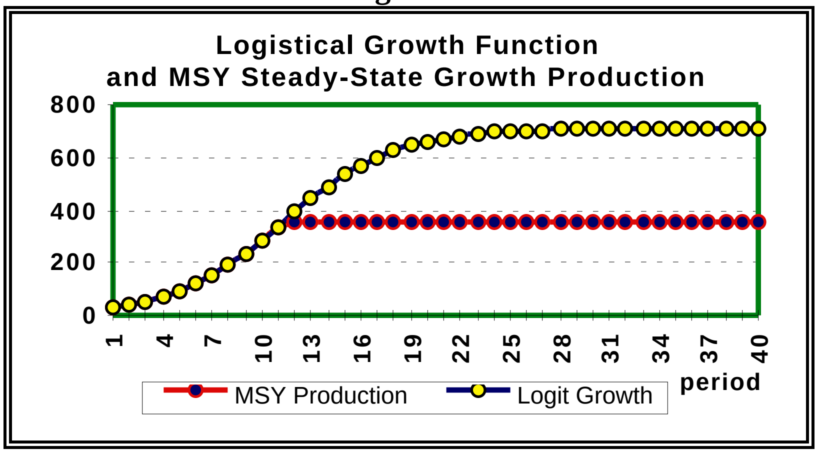
r = *the biological rate of growth of a species,*

t = *the given time period*

The parameters used in these figures are: K = 709.94; r=.3, c=30 , and lim(t)=40. It should be emphasized that we are portraying here only the behavior of single species systems. Ecosystems are much more complex, and the economic valuation framework outlined here ultimately must be expanded to include dynamic interactions in ecosystems along with a corresponding set of multiple economic valuations. See, for example, Marc Mangel and Colin W. Clark, *Dynamic Modeling in Behavioral Ecology* (Princeton, N.J.: Princeton University Press, 1988), and Daniel R. Brooks and E.O. Wiley, *Evolution as Entropy* (Chicago, Illinois: University of Chicago Press, 1986).

the resource is one half of the carrying capacity, and whose point in time can be derived from the underlying logistical growth equation.[37] In turn, if one allows the species to reach its maximum sustainable yield(MSY), as shown at the peak rate in Figure 9, harvesting the MSY each year thereafter will provide steady-state production at approximately half of its carrying capacity, as is shown in Figure 10.[38]

Figure 10



How does the maximum sustainable yield concept enable us to evaluate sustainable economic growth and development in Africa? Let us first go back to our index of natural resource sustainable growth as defined in Table 2. We defined natural resource sustainable growth as a condition in which PPP real per capita income is growing at a rate greater than or equal to the positive rate of growth in natural resources. Under Daly's strong sustainability criterion, no country in our Sub-Saharan Africa has achieved sustainable growth, but as we have seen, there are wide variations in relative performance.

To satisfy the strong sustainability natural resource growth criterion, a country would have to limit its harvest of renewable natural resources to its underlying rate of increase in population, or lower its rate of population increase to a level consistent with the underlying rate of increase in natural resources. If such an economy managed at the same time to achieve increases in its PPP real per capita income, it would then achieve sustainable economic growth.

It is clear is that the relative weakness in physical and human capital accumulation in Sub-Saharan Africa has led to greater reliance on natural capital, and that existing rates of population growth far exceed natural rates of increase in natural capital stocks. To bring countries to a path of sustainable growth, investment must be made not only in physical capital stocks, but also in natural resources.

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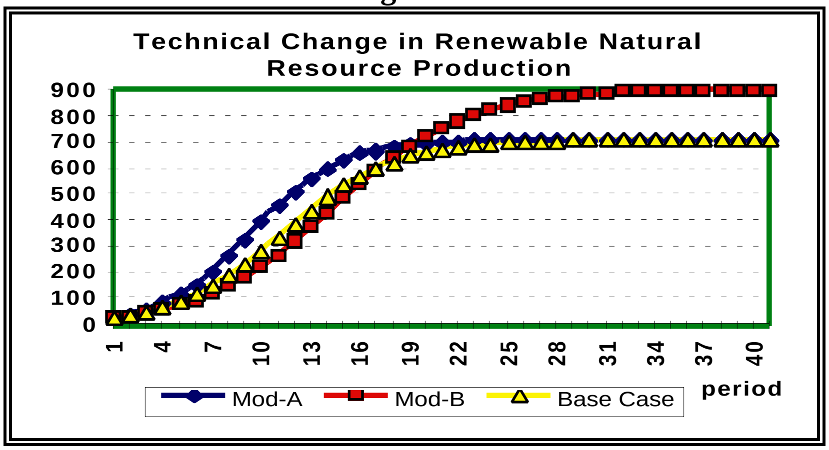
[37] The yield function from a logistical function is given as: $\delta X/\delta t = rX - (rX^2)/K$, where $\delta X/\delta t$ is the rate of output per unit of time, X is the level of output at time t, r is the rate of growth, and K is the carrying capacity of the species. The yield function may be thought of as a probability density function analog of a cumulative probability density function as portrayed in the logistical growth curve. The maximum sustainable yield (MSY) is 53.25, and occurs at t=11.34, as per the following note which specifies the optimal time period that corresponds to the MSY.

[38] From the logit growth equation in note 12, solving for the optimal point of the maximum sustainable yield is obtained by: $t = \log(c) - \log((K/(.5K))-1)/(r*\log(e))$, where K, r, and e are defined as above. The solution in this case is t=11.34.

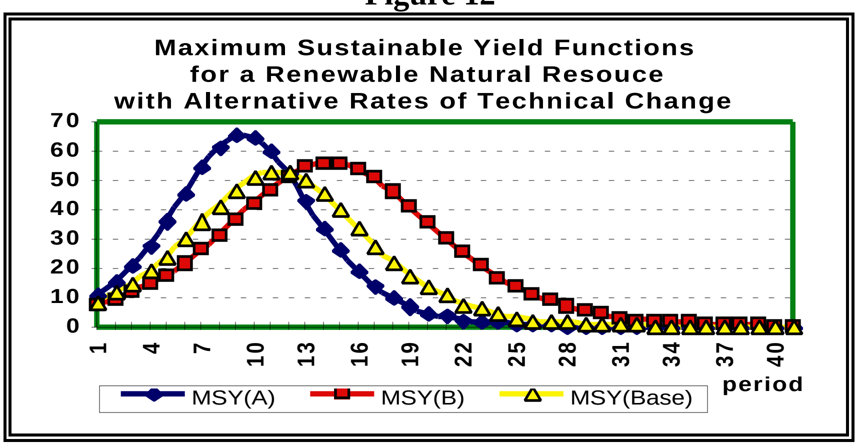
If a country invests in productivity enhancing change in its natural capital, two kinds of changes will occur, which we illustrate in Figure 5.[39] One is an increase in the carrying capacity of a given environment, as shown in Mod-B in Figure 11. Increases in the carrying capacity are a function of both organization of natural resource production, as in the range of agricultural techniques for a given species of a given vintage. The other is an increase in the rate of growth of a natural resource, as a result of the use of nutrient enrichment, irrigation, and biotechnology that results in faster growing species of a given natural resource. We can view these variants respectively as disembodied and embodied technical change.

Figure 11



Whether investment in natural resources produces increases in the carrying capacity of the environment and/or whether it produces accelerated rates of growth of a species, there will be a corresponding increase in the maximum sustainable growth and yield harvest functions, as shown in Figures 12 and 13. From both the alternative logit growth functions or from the maximum sustainable yield functions, if the rate of population growth remains constant, obviously there will be a greater rate of natural resource growth, and thus greater sustainability.[40]

Figure 12

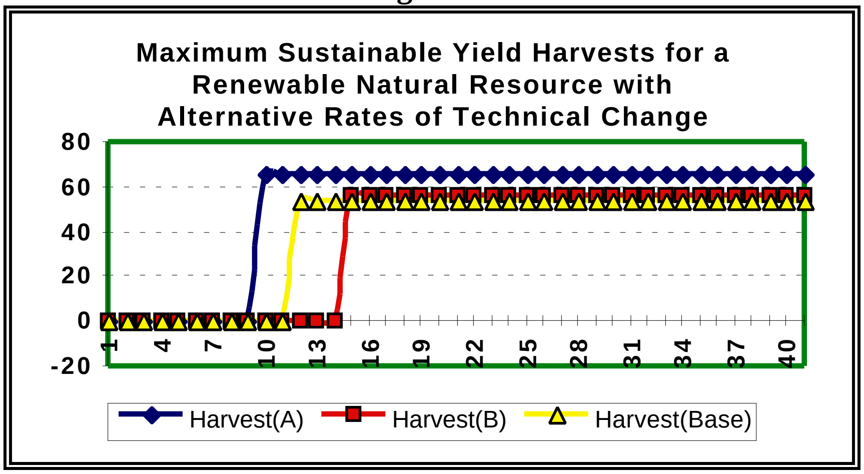


[39] For Mod-A, K=709.94, r=.37, and c=32.17, which generates an MSY of 65.67 in period 9.38; for Mod-B, K=900, r=.25, and c=36.52, which generates an MSY of 56.25 in period 14.39. This compares with the base case of K=709.94, r=.30, c=30, with a corresponding MSY of 53.25 at period 11.34.

[40] Our model of sustainable harvesting ultimately should be modified to take into consideration the marginal costs of harvesting. Including marginal costs results in optimal harvesting rates that typically are less than at the maximum sustainable yield level. Since harvesting any natural resource involves positive marginal costs, net present social values will be lowered accordingly. Any solution to economically and environmentally sustainable growth thus will be at rates less than the maximum sustainable yield level.

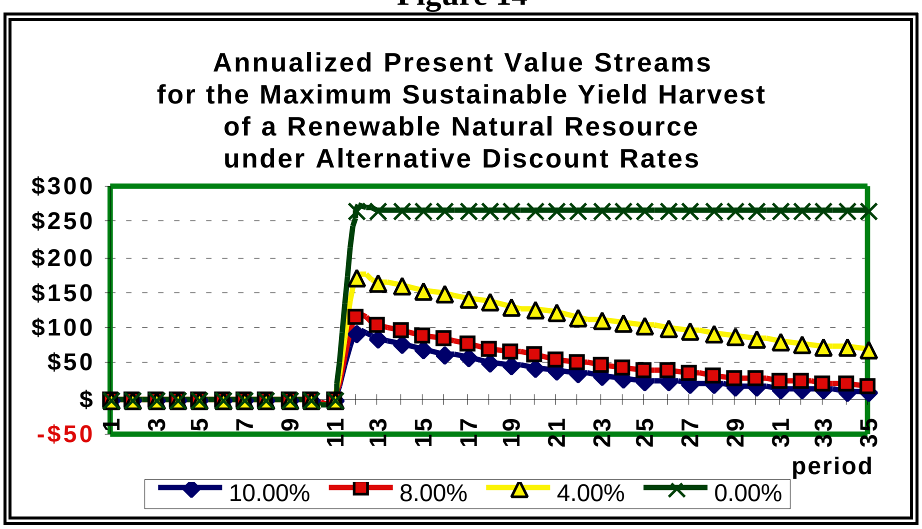
The alternative maximum sustainable yield functions of Figures 12 and 13 point to a critical issue in natural resource management. Assuming for the moment that one were to use the MSY functions as a basis for selecting sustainable harvests, because the MSY occurs at different points in time, we now need to take into consideration the economic costs and benefits of alternative investment choices.

Figure 13



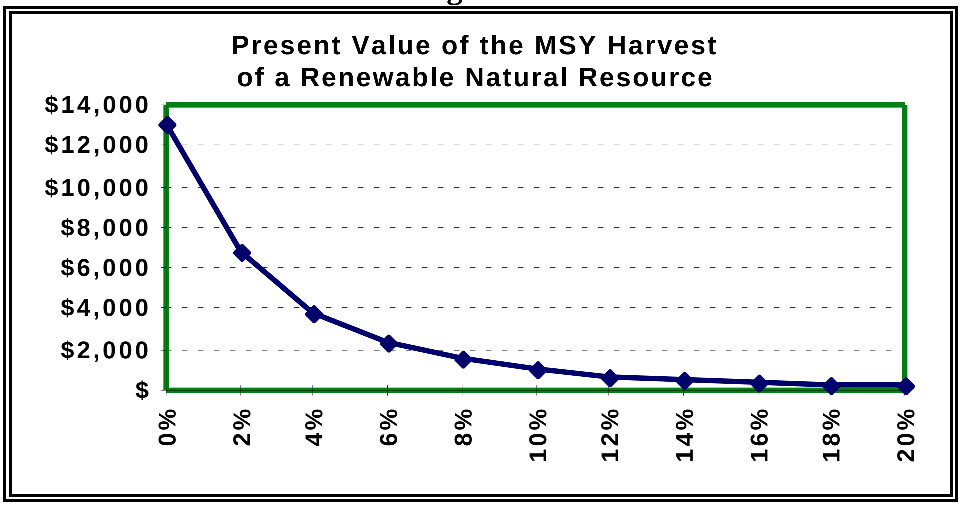
One simple variation is that the logit growth function of a given species reaches its carrying capacity within a relatively short time period, e.g., an annual growth cycle. In this case, the issue of discounting is relatively minor and one can derive the optimal planting and harvesting choice of a given species in terms of its underlying economic costs and benefits. As long as the marginal benefit exceeds the marginal cost, additional resources should be committed to the production of the species.

Figure 14



A more interesting case arises when a given species does not achieve its maximum sustainable yield within a given annual growing cycle. In this case, other things equal, for a given natural resource, we need to calculate the net present value of the species in order to arrive at an optimal production decision. As a first approximation, we will take our base case resource, assume for the moment that we are going to use the MSY harvest level, as portrayed in Figure 13, and then calculate the annualized present values of the resource, as is shown above in Figure 14, and for which the sum is the Present Value of the MSY harvest, as shown in Figure 15:[41]

Figure 15



Determination of the optimal investment in a renewable natural resource can now be determined as the net present value of the resource at the opportunity cost of capital, or discount rate. As long as the Net Present Value(or NPV) of the investment discounted at the opportunity cost of capital is positive, the investment should be undertaken.

V. Economic Incentives for the Efficient Valuation of Natural Resources

Although we have now established a basic economic framework for investment in natural resources, it does not follow that the necessary institutions are in place to achieve an efficient allocation of resources. It also does not follow that an efficient allocation of resources also will be sustainable. Furthermore, even if we achieve sustainable growth through the maximum sustainable yield criterion, this may not necessarily be the optimal harvest rate for a renewable natural resource, especially if we take into account the present value of the marginal cost of production in comparison to the present value of the marginal benefit. In this section, we look at each of these considerations with the goal of establishing appropriate economic incentives for the efficient valuation of natural resources, and in a way that is consistent with sustainable growth.

Let us consider for our present purposes the question of a pure allocation of resources necessary to achieve sustainable growth in natural resources per capita. We will thus set aside the question of external effects such as environmental pollution that arise from any economic process, and we also will defer consideration of the issue of property rights. In this simplified framework,

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[41] Using the MSY, since it will be generated in perpetuity for the life of the renewable natural resource, we multiply the quantity in each time period times the market value of the harvested resource. In Figure 7, we are using a price of $5.00 times the MSY of 53.25, or VMSY, beginning in period 12, at alternative discount rates of 10%, 8%, 4% and 0%. The lower the discount rate, the closer the annualized present values will approximate a constant stream of benefits, with the zero discount option shown in blue at the top in Figure 7. These streams are thus given as: $APV = \frac{VMSY_0}{(1+r)^0}, \frac{VMSY_1}{(1+r)^1}, \frac{VMSY_2}{(1+r)^2} \ldots$, which when added together yield the present value: $PV = \sum_{t=0}^{n} \frac{VMSY_t}{(1+r)^t}$

The continuous time version of the present valuation is: $\int_0^t (\text{VMSY}) e^{-rt} dt - \int_0^{t(msy)} (\text{VMSY}) e^{-rt} dt$. In both cases, present valuations must take into account that no harvesting would begin until the maximum sustainable yield is achieved. Since we are looking only at the present value of benefits, the MSY may not be economically optimal once one takes costs into consideration.

the question now is what amount of investment is necessary to guarantee that a constant or increasing level of natural resources per capita will be available. If the population growth rate is zero, we thus can calculate the ratio of per capita natural resources that will be available under the maximum sustainable yield. While some would stipulate that this ratio should also be coupled with a minimum target level consistent with human reproduction, we will consider here only the economic requirements necessary to achieve the maximum sustainable yield.

The first point is that if maximum sustainable yield requires deferred consumption until a natural resource has reached its maximum sustainable yield rate, there will be zero consumption of this resource up to the point where maximum sustainable yield harvests can be undertaken, much as was illustrated in Figures 13 and 14. The question then is, even in the presence of a zero population growth rate, how could one arrive at sustainable economic growth in which the maximum sustainable yield of the resource is invariant over time?

The answer is that there must be technical change in the consumption of the natural resource such that a higher level of per capita income can be achieved from a constant production stream of the renewable natural resource. Here we are looking at the underlying thermodynamics of natural resource conversion. As one moves from lower entropy to higher entropy conversions, the marginal cost of additional efficiency will rise. As long as the economic return to each additional conversion is at least equal to the opportunity cost of capital, the process can continue. There is, however, no automatic mechanism that will guarantee this outcome, particularly if technological change in the conversion of renewable natural resources is a discontinuous process dependent on an uneven flow of innovation.

What happens when a renewable natural resource is produced under conditions of increasing population? Here the problem is more complicated in that we confront the twin issues of the necessary waiting period before a maximum sustainable yield harvest can begin, and the fact that this will no longer correspond to a sustainable growth standard over time. This means that there must be a stream of investment necessary to raise the maximum sustainable yield level in such a way that the per capita level of natural resource availability over time is constant or increasing. John Pezzey has derived the conditions necessary to achieve sustainable growth under these conditions.[42] His solution, for a single species, is that sustainable welfare growth, i.e., per capita income growth with a constant level of renewable natural resources per capita, is possible as long as the renewable natural resource growth rate exceeds the sum of both the discount rate and the population growth rate.

Several conclusions can be derived from the framework of renewable resource growth models. One is that as long as population is increasing, investment in renewable resource production must

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[42] John Pezzey, "Economic Analysis of Sustainable Growth and Sustainable Development" Working Paper No. 15 (Washington, D.C.: World Bank Environment Department, 1989). Pezzey's essay defines not only the necessary condition for sustainable growth in per capita welfare, but also the necessary condition that the per capita renewable natural resource base meets some other minimum criterion, e.g., biological reproducibility of the human species based on the initial production conditions of the renewable natural resource. Pezzey's formulation, which he characterizes as a 'corn-eating' model with a minimum subsistence level, can be summarized maximizing the present discounted value of utility derived from a personally-owned stock over an infinite time horizon:

Maximize $\int_0^\infty u[c(t)]e^{-(\partial-\lambda)t}dt$. By maximizing discounted unweighted utility, the differential equation optimal solution for the optimal corn stock s(t) is $(1-v)\ddot{s}+[\partial-\gamma(2-v)]\dot{s}+\gamma(\gamma-\partial)s=(\gamma-\partial)c_m$, where $\gamma=\rho-\lambda$. This linear equation yields the following solutions for per capita variables: Resource stock $s^*(t)=c_m//\gamma + (s_O - c_m/\gamma)e^{\eta t}$, where $\eta=(\rho-\lambda-\delta)/(1-\upsilon)$; Consumption $c^*(t)= c_m + (\gamma-\eta)(s_0-c_m/\gamma)e^{\eta t}$; and utility $u^*(t) = [(\gamma-\eta)(s_0-c_m/\gamma)e^{\eta t}]^v$.

be made at a rate that generates at least a constant stock of renewable resources per capita if sustainable growth is to be achieved. While one could focus on ways to temper the rate of growth of population to prevailing rates of natural resource production, as long as investments in renewable resource technologies result in expanding renewable resource production at rates equal to population growth, one can set aside the difficult question of family planning policies. However, for most countries, even with positive rates of expansion in renewable resource production, because the margin of returns to renewable resource investment may be thin, some consideration usually is given to policies that can slow the rate of population growth.[43]

For countries in Africa, where population growth rates remain among the highest in the world, consideration should be given to evaluating the returns to investment in expanding resource productivity in comparison to investment in family planning programs. Good governance, along with establishing clearly defined property rights, are major considerations in making such comparisons. Projects that provide technical demonstrations of the returns to investment in various natural resource programs often fail in that the necessary conditions for their adoption in the local community may be partly or wholly absent. Aid programs thus need to strengthen the emphasis on agroecosystems as a key to sustainable growth initiatives.[44]

Another conclusion from renewable resource models is that even if population growth does not occur, sustainable growth still will require an expansion of the productivity of renewable natural resources. The reason why this is so is that as investments in expanding the stock of exhaustible natural resources eventually reach diminishing returns, sustainable growth will require a shift to high technology renewable resource use, as already noted in section IV.

Thirdly, if renewable resources are to be economically efficient, property rights regimes must be clearly defined so that resources can be priced at their social opportunity cost. Establishing property rights does not in and of itself resolve the problem of the valuation of natural capital. Indeed, it very much depends on how these property rights are defined. They could, for example, be assigned to the state, which has often been the case in post-colonial Africa. They also could be assigned to a local community, which has often been the case in pre- and post-colonial Africa. And they also could be assigned to individuals with varying degrees of contractual exchange choice.

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[43] China is the most striking example of family planning with its one family one-child rule. In Africa, family planning programs do exist, but what appears to be the greatest determinant in limiting family size is education and economic growth. The debate on family planning was joined by Julian Simon in *The Ultimate Resource* (Princeton: Princeton University Press, 1996), in which he argued that there are no limits to growth that would require the imposition of family planning since education and economic growth would be sufficient conditions for sustainable growth. Simon's most noted critic has been Paul R. Ehrlich. See, for example, *Ecological Economics and the Carrying Capacity of the Earth* (Washington, D.C.: Island Press, 1994). Ehrlich lost a wager with Simon back in the 1980's over whether commodity prices would continue to rise throughout the decade in response to growing scarcity, in an echo of the Limits to Growth debate of the 1970's. Our goal here is not to review the literature on this debate, but rather to set out the conditions under which sustainable economic growth may or may not take place. See also Richard P. Cincotta and Robert Engelman, "Economics and Rapid Change: The Influence of Population Growth" (Washington, D.C.: Population Actional International, Occasional paper Number 3, October 1997), and Michael B. Jenkins, project director, "Sustaining Profits and Forests" (Chicago, Illinois: The John D. and Catherine T. MacArthur Foundation, 1998).

[44] The Agricultural Policy Analysis Project (APAP), the Environmental and Natural Resources Policy and Training Project (EPAT), the Consultative Group on International Agricultural Research (CGIAR), and the International Rice Research Institute (IRRI) receive substantial support from U.S.AID missions. What often is missing in these initiatives is a set of clear performance benchmarks against which an economic evaluation of policy alternatives may be considered.

Fourthly, decentralization of property rights as closely as possible to end users is certainly an important element of an efficient system. However, the principal factor that will determine economic efficiency in the use of natural resources is the extent to which transactions costs involving property rights can be minimized, as was noted long ago by Ronald Coase.[45] As countries embrace national environmental action plans, what is needed is to provide explicit consideration of the transactions costs associated with the transfer and use of property rights in natural resource management. Unless systems can be adopted that keep transactions costs relatively low, markets will fail to provide for an efficient allocation of natural resources, and sustainable growth initiatives will be limited accordingly.

Where, then, does this leave us in terms of the role of economics in achieving sustainable growth and development in Africa? As noted in the beginning of this paper, African countries place growing emphasis on policies designed to achieve sustainable growth and development. Unfortunately, many of these initiatives still tend to be highly centralized and undertaken with little regard to the social costs of implementation. While these conventions may provide lists of what is permitted and what is not, regulation as such does not produce an efficient economic valuation of natural resources. Absent such economic valuation, we will continue to witness a process of periodic revision of regulated lists, using at best proxy measures of natural resource value where no incentive to reach such an evaluation has been established. While better than doing nothing, it wavers between outright prohibition to achieve no use and overuse because of incomplete estimates of the underlying dynamics of natural resource stocks. Clearly, we need to develop comparability yardsticks for these conventions, and to link them to broader measures of economic and social welfare, which is why economic measurement is important. Ultimately, it is not just the adoption of economic measures of natural resource use, but the creation of incentives that can enable market-based institutions to allocate these resources in a more sustainable fashion than has been the case up to now.

[45] Ronald Coase, "The Problem of Social Cost," *Journal of Law and Economics* (October 1960), 3: 1-44. While Coase's article signaled the importance of transactions costs to the determination of property rights, it did not determine on what basis property rights would evolve. As pointed out in note 21, the literature on transactions costs and property rights has expanded substantially, and extends not just to market transactions, but also to the structure of firms. See, for example, Oliver Williamson, *Markets and Hierarchies* (New York: The Free Press, 1975); Yoram Barzel, *Economic Analysis of Property Rights* (New York: Cambridge University Press, 1989); Barnard Salanié, *The Economics of Contracts* (Cambridge: MIT Press, 1997); and Susan S. Hanna, Carl Folke, and Karl-Gîran MÑer, *Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment.* Washington, D.C.: Island Press, 1996). As much of this literature affirms, the assignment and efficiency of economic property rights turns critically on the level and distribution of information. As noted in section IV.A, efficient markets depend ultimately on the capacity of market institutions to develop products to manage decisions in the presence of incomplete information. Futures and options markets in natural resources thus have an important role to play in helping to reduce transactions costs, and thus to generate a process for the socially efficient allocation of these resources.

Table A.1
Sub-Saharan Africa Energy Profile

	Population Millions 1995	Population Growth Rate 1995-2010	PPP GNP $millions 1995	PPP GNP/P.C. 1995	Comm.En. Prod. 1994 10^3 mtoe	Comm.En. Cons.1994 10^3mtoe	Energy Import Dependence KG Per Capita	Energy Consumption KG per capita	Energy Efficiency KG per $GNP
Angola	11	2.80	$14,410	$1,310	24914	931	2180.27	84.64	0.06
Benin	5	2.60	$8,800	$1,760	315	107	41.60	21.40	0.01
Botswana	1	1.70	$5,580	$5,580	248	549	-301.00	549.00	0.10
Burkina Faso	10	2.60	$7,800	$780	0	160	-16.00	16.00	0.02
Burundi	6	2.50	$3,780	$630	5	143	-23.00	23.83	0.04
Cameroon	13	2.90	$27,430	$2,110	5782	1335	342.08	102.69	0.05
CAR	3	2.00	$3,210	$1,070	22	93	-23.67	31.00	0.03
Chad	6	2.40	$4,200	$700	0	100	-16.67	16.67	0.02
Congo	3	2.60	$6,150	$2,050	9428	847	2860.33	282.33	0.14
Côte d'Ivoire	14	2.20	$22,120	$1,580	425	1406	-70.07	100.43	0.06
Ethiopia	56	2.80	$25,200	$450	156	1193	-18.52	21.30	0.05
Gabon	1	2.30	$3,500	$3,500	15998	692	15306.00	692.00	0.20
The Gambia	1	2.10	$930	$930	0	60	-60.00	60.00	0.06
Ghana	17	2.40	$33,830	$1,990	523	1542	-59.94	90.71	0.05
Guinea	7	2.80	$4,550	$650	57	418	-51.57	59.71	0.09
Guinea-Bissau	1	2.10	$790	$790	0	39	-39.00	39.00	0.05
Kenya	27	2.20	$37,260	$1,380	488	2872	-88.30	106.37	0.08
Madagascar	14	2.80	$8,960	$640	83	479	-28.29	34.21	0.05
Malawi	10	2.40	$7,500	$750	152	370	-21.80	37.00	0.05
Mali	10	3.00	$5,500	$550	42	205	-16.30	20.50	0.04
Mauritania	2	2.30	$3,080	$1,540	0	229	-114.50	114.50	0.07
Mauritius	1	1.00	$13,210	$13,210	34	431	-397.00	431.00	0.03
Mozambique	16	2.40	$12,960	$810	161	619	-28.63	38.69	0.05
Namibia	2	2.30	$8,300	$4,150	0	1624	-812.00	812.00	0.20
Niger	9	3.20	$6,750	$750	55	327	-30.22	36.33	0.05
Nigeria	111	2.60	$135,420	$1,220	102138	17503	762.48	157.68	0.13
Rwanda	6	3.50	$3,240	$540	46	209	-27.17	34.83	0.06
Senegal	8	2.50	$14,240	$1,780	0	803	-100.38	100.38	0.06
Sierra Leone	4	2.70	$2,320	$580	0	323	-80.75	80.75	0.14
South Africa	41	1.90	$206,230	$5,030	117691	86995	748.68	2121.83	0.42
Sudan	27	2.20	$11,880	$440	81	1731	-61.11	64.11	0.15
Tanzania	30	2.60	$19,200	$640	165	95	2.33	3.17	0.00
Togo	4	2.70	$4,520	$1,130	0	183	-45.75	45.75	0.04
Uganda	19	2.60	$27,930	$1,470	179	425	-12.95	22.37	0.02
Zaire	44	2.50	$21,560	$490	1877	1902	-0.57	43.23	0.09
Zambia	9	2.10	$8,370	$930	890	1296	-45.11	144.00	0.15
Zimbabwe	11	1.60	$22,330	$2,030	3567	4722	-105.00	429.27	0.21

Source: The World Bank, *World Development Indicators 1997*.

Table A.2

Sub-Saharan Africa Natural Resource Indicators

	Arable Land % 1994	Cropland Km2 1994	Perm.Past. Km2 1994	Other Land Km2 1994	Forest Area Km2 1994	Total Land Km2 1994	Population Millions 1995	Population Growth Rate 1995-2010	PPP GNP $billions 1995	PPP GNP/P. 1995
Angola	2	30.48	436.88	548.64	231	1247.00	11	2.80	$14,410	$1,3
Benin	13	10.54	2.48	48.98	49	111.00	5	2.60	$8,800	$1,7
Botswana	1	4.24	190.80	228.96	143	567.00	1	1.70	$5,580	$5,5
Burkina Faso	13	29.90	50.60	149.50	44	274.00	10	2.60	$7,800	$7
Burundi	39	11.04	9.36	3.60	2	26.00	6	2.50	$3,780	$6
Cameroon	13	7.83	10.44	242.73	204	465.00	13	2.90	$27,430	$2,1
CAR	3	9.51	15.85	291.64	306	623.00	3	2.00	$3,210	$1,0
Chad	3	34.35	412.20	698.45	114	1259.00	6	2.40	$4,200	$7
Congo	0	0.00	41.47	101.53	199	342.00	3	2.60	$6,150	$2,0
Côte d'Ivoire	8	25.08	85.69	98.23	109	318.00	14	2.20	$22,120	$1,5
Ethiopia	10	231.66	171.60	454.74	142	1000.00	56	2.80	$25,200	$4
Gabon	1	1.52	13.68	60.80	182	258.00	1	2.30	$3,500	$3,5
The Gambia	17	1.53	1.71	5.76	1	10.00	1	2.10	$930	$9
Ghana	12	25.08	48.84	58.08	96	228.00	17	2.40	$33,830	$1,9
Guinea	2	5.37	78.76	94.87	67	246.00	7	2.80	$4,550	$6
Guinea-Bissau	11	0.96	3.04	4.00	20	28.00	1	2.10	$790	$7
Kenya	7	44.56	206.09	306.35	12	569.00	27	2.20	$37,260	$1,3
Madagascar	4	21.20	173.84	228.96	158	582.00	14	2.80	$8,960	$6
Malawi	18	10.62	11.80	36.58	35	94.00	10	2.40	$7,500	$7
Mali	2	21.98	274.75	802.27	121	1220.00	10	3.00	$5,500	$5
Mauritania	0	0.00	387.22	631.78	6	1025.00	2	2.30	$3,080	$1,5
Mauritius	49	0.52	0.03	0.45	1	2.00	1	1.00	$13,210	$13,2
Mozambique	4	24.44	342.16	244.40	173	784.00	16	2.40	$12,960	$8
Namibia	1	5.34	5.34	523.32	289	823.00	2	2.30	$8,300	$4,1
Niger	3	37.29	99.44	1106.27	24	1267.00	9	3.20	$6,750	$7
Nigeria	33	271.80	332.20	151.00	156	911.00	111	2.60	$135,420	$1,2
Rwanda	35	10.81	6.44	5.75	2	25.00	6	3.50	$3,240	$5
Senegal	12	14.16	35.40	68.44	75	193.00	8	2.50	$14,240	$1,7
Sierra Leone	7	4.24	16.43	32.33	19	72.00	4	2.70	$2,320	$5
South Africa	10	129.36	787.92	258.72	45	1221.00	41	1.90	$206,230	$5,0
Sudan	5	97.30	895.16	953.54	430	2376.00	27	2.20	$11,880	$4
Tanzania	3	21.92	219.20	306.88	336	884.00	30	2.60	$19,200	$6
Togo	38	18.00	1.60	20.40	14	54.00	4	2.70	$4,520	$1,1
Uganda	25	46.58	12.33	78.09	63	200.00	19	2.60	$27,930	$1,4
Zaire	3	34.02	79.38	1020.60	1133	2267.00	44	2.50	$21,560	$4
Zambia	7	29.40	168.00	222.60	323	743.00	9	2.10	$8,370	$9
Zimbabwe	7	20.86	131.12	146.02	89	387.00	11	1.60	$22,330	$2,0
Total		**1293.49**	**5759.25**	**10235.26**	**5413.00**	**22701.00**	**560.00**		**$753,040**	
Average	**11.38**	**34.96**	**155.66**	**276.63**	**146.30**	**613.54**	**15.14**	**2.43**	**$20,352**	**$1,7**

Source: World Bank, *World Development Indicators, 1997* .