ECOLOGICAL ECONOMICS

Brian Czech

Center for the Advancement of the Steady State Economy, 5101 South 11th Street., Arlington, Virginia 22204, USA

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Summary

Ecological economics arose in the final decades of the 20th century out of concerns for environmental protection and economic sustainability. It was largely a response to a real or perceived lack of physical and biological underpinnings in neoclassical economics. It was also intended to infuse economics with a moral philosophy, in contrast with the amoral implications of neoclassical models portraying man as a rational, utility-maximizing automaton.

Ecological economics is a transdisciplinary endeavor, incorporating and synthesizing concepts and findings from an array of natural and social sciences. Of particular importance are the laws of thermodynamics and basic principles of ecology. Limits to economic growth are thoroughly understood only via the first two laws of thermodynamics. The first law establishes that there is a limit to the inputs required for economic production, and the second law establishes that there are limits to the efficiency with which those inputs may be transformed into goods and services. Similarly, ecological concepts such as trophic levels, niche breadth, and competitive exclusion are required for a thorough understanding of the relationship between the human economy and the diversity of nonhuman species, or the "economy of nature."

Given its roots in the natural sciences and moral philosophy, the major themes of ecological economics are scale, distribution, and allocation. Scale refers to the size of the human economy relative to its containing, sustaining ecosystem. Because scale is limited – i.e., there is a limit to economic growth – the distribution of wealth is a topic that must be addressed, with public policy if necessary, if poverty is to be alleviated. Prioritizing scale and distribution distinguishes ecological economics from neoclassical economics, which posits unlimited economic growth and therefore implies that a "rising tide lifts all boats." In neoclassical economics, the efficient allocation of resources among producers is the primary concern. Efficient allocation of labor and capital, especially, is thought to help maximize production and boost rates of economic growth. In ecological economics, efficient allocation is also recognized as an important objective, but the importance of land and natural resources as a factor of production is emphasized. Natural resources are found to be only partially substitutable by labor and manufactured capital. In ecological economics, individual natural resources are also scrutinized to determine if they have the properties necessary for being allocated efficiently in the market. Many natural resources and services provided by ecosystems (such as pollination, climate regulation, and water purification) are often found to be lacking such properties and are therefore overused or ignored unless protected by forces outside of the market.

Based upon its themes and findings, ecological economics produces a number of distinctive policy implications. Some new policies are required, and many existing policies must be reformed if the goals of sustainable scale, fair distribution, and efficient allocation are to be met. For sustainable

scale, the vast array of fiscal, monetary, and trade policies that are designed to stimulate economic growth may be gradually re-adjusted to make them conducive to a steady state economy with stabilized production and consumption of goods and services in the aggregate. Additional policies such as caps on extraction and pollution may be necessary for assuring sustainable scale and more closely approximating optimal scale.

Facing limits to growth, societies are likewise faced with challenging choices about dealing with poverty. Progressive taxes are a traditional method for doing so. Caps on income and wealth, minimum income, and the distribution of returns from natural resources are additional options proffered in ecological economics.

For efficient allocation of resources, many of the policy recommendations stemming from "environmental economics," or neoclassical economics as applied to environmental issues, are supported by ecological economics as well. These policies are focused on correcting for market imperfections of natural resources when it is feasible to do so. The contribution of ecological economics to the use of these corrective policies is primarily in the deeper understanding of the components, structures, and functions of ecosystems that need to be evaluated in order to identify the corrective course. This understanding is usually procured through the collaboration of economists with ecologists, or by the cross-training of individuals in ecology and economics, and it is often used in estimating values of natural capital and ecosystem services in monetary terms. With such estimates, markets may be designed or modified to allocate the resources. However, in ecological economics, the need for non-market mechanisms for allocating or conserving some natural resources and ecosystem services is readily recognized, and regulations are viewed as efficient policy tools in many such cases, whereas the neoclassical faith in the market tends to dissuade the polity from adopting conservation regulations.

Ecological economics will be one of the most important endeavors of the 21st century as nations and the world population approach, breach, and adjust to supply shocks such as Peak Oil and environmental crises such as climate change. For numerous reasons including the vast reach of neoclassical economists in academia, commerce, and government, ecological economics will be challenged to avoid a pre-occupation with natural capital valuation exercises at the expense of its distinguishing emphasis on sustainable scale. Ecological economics has come along none too soon, as indicated by the fact that the steady state economy as a macroeconomic policy goal must also be reconciled with legitimate calls for economic de-growth.

1. Historical Development of Ecological Economics

Ecological economics arose in response to mounting environmental problems that were witnessed by the public and documented by scientists in books such as Rachel Carson's *Silent Spring* (1962), Barry Commoner's *The Closing Circle* (1971), and *The Limits to Growth* (1972) by Donnella Meadows et al. Many observers were disappointed with the approach of conventional or "neoclassical" economics to environmental degradation, exemplified by Howard Barnett and Chandler Morse (*Scarcity and Growth*, 1963), who believed that prices in a well-functioning market would prevent crippling resource shortages. Neoclassical economists and business professors such as Julian Simon invariably prescribed economic growth as the solution to virtually all social problems, even environmental problems and especially pollution. According to them, conflicts between economic growth and environmental protection could be solved via technological progress.

One of the first well-trained economists to part ways with the neoclassical school on environmental grounds was Herman Daly, whose *Steady-State Economics* (1977) provided an alternative vision for a sustainable, equitable economy in balance with the environment. Daly was Professor of Economics at Louisiana State University when he wrote *Steady-State Economics*, and served as a Senior Economist at the World Bank from 1988-1994. His professional leadership and writing talents attracted many other economists, and also ecologists concerned with environmental protection. Ecologists found in *Steady-State Economics* a refreshing familiarity with the natural sciences as well as economic principles. Daly, a protégé of Nicholas Georgescu-Roegen (*The Entropy Law and the Economic Process*, 1971), was particularly adept with the laws of thermodynamics and the implications of thermodynamics for economic growth. Other prominent and productive figures with similar emphases and outlooks included Kenneth Boulding, Robert Ayres, and E. F. Schumacher.

Key figures in the development of ecological economics assembled during the 1980s, most notably in Stockholm in 1982 (organized by AnnMari Jansson) and Barcelona in 1987 (organized by Joan Martinez-Alier). These meetings helped the participants to identify common ground, complementary skills, and major challenges to developing a more ecologically sound theory and practice of economics. Many of the attendees would become prominent contributors to the ecological economics literature and related institutions. One of them was Robert Costanza, who took the lead in establishing the International Society for Ecological Economics in 1988. Costanza was a student of the systems ecologist H. T. Odum (1924-2002) and brought his own mastery of thermodynamics with additional ecological and economic applications. Costanza served as the editor of *Ecological Economics* from its inception in 1989 until 2002 and has been one of the most prolific authors in the ecological economics literature at large.

The first ISEE conference was held in 1990, with bi-annual conferences held since. By 2007 there were nine ISEE-affiliated regional societies representing Australia-New Zealand, Argentina-Uruguay, Africa, Brazil, Canada, Europe, India, Russia, and the United States. (There was also a non-affiliated Chinese Ecological Economics Society and an Iberian and Latin American Network of Ecological Economics.)

With regard to the broader sweep of history, one of the more noteworthy roots of ecological economics was the work of Francois Quesnay and the physiocrats of late 18th century France. Quesnay was brought into the king's court as a physician and became a general advisor. He developed a strong interest in agriculture and, with his medical background, viewed the French economy as a circulatory system of goods and services, as described in the *Tableau Economique* (1759). The most important point of the *Tableau* was his designation of agriculture as the sole source of economic production, with all other economic activities deriving from that production.

Adam Smith met Quesnay and studied the *Tableau* prior to writing the *Wealth of Nations* (1776). Although he disagreed with Quesnay's categorization of agriculture as the sole source of production, he nevertheless described how agricultural surplus was necessary for the division of labor. There was no argument about the primacy of agricultural surplus among the classical economists, even in the midst of the industrial revolution, but as their studies of "political economy" splintered into neoclassical economics and political science at the dawn of the 20th century, microeconomics eclipsed the broader, integrated vision of the economy. Future economists would not be as familiar with the inter-relationships among economic sectors, much less with the natural sciences or agricultural practices. Meanwhile, much of the vacuum in political economy was occupied by Marxists and followers of Henry George, the latter calling for a singular and substantial tax on land rents in *Progress and Poverty* (1879).

When Henry George followed up on *Progress and Poverty* with political activism and attained broad support from populist followers, land barons teamed with hand-picked economists to downplay the role of land in economic production in order to refocus tax policy on wages. Many economics departments in the United States were in their formative stages and the anti-George backlash manifested in the development of neoclassical economics. By the time macroeconomics was borne of the Keynesian revolution in the second quarter of the 20th century, agricultural economics was consigned to its own corridors. Among the broader economics community, land was generally overlooked as a factor of production while economists focused on labor and capital. War-time economics were especially focused on capital mobilization while the Great Depression prompted a focus on labor and employment. Furthermore, the developed countries were urbanizing at a rapid rate, with citizens evermore removed from the land. These developments in social and political context help to explain the growing propensity of 20th century neoclassical economists to underestimate the magnitude and implications of natural resource scarcity and environmental deterioration. Conversely in ecological economics, the fundamental requirement of agricultural surplus for a fully developed economy – and increasing surplus for a *growing* economy – is a cornerstone in the theoretical foundation.

One classical economist with exceptional relevance to ecological economics was John Stuart Mill. In *Principles of Political Economy* (1848), he synthesized the state of the art in economics to that time. He was also perhaps the first economist to advance with hope the notion of the "stationary state" as opposed to warning of it as had Thomas Malthus and David Ricardo, who pointed gloomily to the collision of population growth and agricultural capacity, prompting observers to refer to economics as the "dismal science." Mill believed that an informed human citizenry could come to control its population, achieve a comfortable standard of living, then turn its attention to matters of social justice. The stationary state – a non-growing, non-declining economy – is synonymous for practical purposes with the steady state economy of ecological economics.

The role of Marxist thought in the development of ecological economics is not entirely clear. The founders of ecological economics recognized the pre-occupation with growth in capitalist (and other) economies as a major threat to the environment and society, so "green" Marxists were natural allies. On the other hand, Marx himself appeared to have substantial faith in technology to obviate limits to growth; his critique of capitalism stemmed more from his thoughts on the concentration of power and the maldistribution of wealth. One of the legacies of Marxist vs. capitalist ideology was an arms race between the United States and the Soviet Union, a Cold War in which the score was kept in terms of economic production. The pre-occupation of these powers with economic growth was one factor in speeding the human race into environmental deterioration, and into the study of ecological economics.

2. Approach and Philosophy of Ecological Economics

The general approach and philosophy of any endeavor are interrelated, so are treated here in the same section. Ecological economics has an approach and philosophy that distinguishes it from neoclassical economics and from most "heterodox" economics traditions such as the Austrian School, Keynesian economics, and Marxism. The approach and philosophy of ecological economics may be concisely described as transdisciplinary and normative, respectively.

2.1 Transdisciplinarity

Ecological economics is sometimes referred to as a "transdisciplinary" endeavor to distinguish it from a long line of "interdisciplinary" studies that arose in academia during the latter decades of the 20th century. The movement toward integration and synthesis of disciplinary studies in some corners of academia resulted from a concern that the policy implications stemming from reductionist science were impractical or misguided. Even numerous efforts at interdisciplinary studies were criticized for mere coupling of reductionist disciplines, however, and the transdisciplinary approach was advanced as cooperative problem-solving with dynamic integration of philosophical perspectives and scientific findings.

The concern with disciplinary reduction was especially warranted with regard to the ecological aspects of economic systems, because many national economies had grown to an extent that pushed the limits of sustainability, and global environmental problems related to economic production such as depletion of the ozone layer, biodiversity loss, and climate change were becoming evident. Most ecologists knew little about the economic processes giving rise to environmental problems, and most economists knew little about the severity or economic implications of ecological degradation. Many ecologists and economists knew little about the political and sociological influences upon their studies and their occasional policy recommendations. It was in this context that Daly, Costanza, Richard Norgaard and others advanced the concept of transdisciplinarity, which may itself be considered a theme or an emphasis of ecological economics.

Nevertheless, a transdisciplinary approach assumes there is something to apply it to, and ecological economics applies it to three primary themes, which may be summarized as scale, distribution, and allocation.

2.2 Ends, Means, and a Normative Stance

Perspectives on human nature and civil rights strongly influence how economic theory is developed, interpreted, and applied. Although there is no consensus in ecological economics about the spiritual origins or ethical nature of man, there is a general consensus that economics is irreducibly a normative endeavor, in study and in practice. This distinguishes ecological economics from neoclassical economics, in which man is modeled as "*Homo economicus*," a self-interesed, utility-maximizing automaton, with utility indicated by the consumption of goods and services. In ecological economics, man is viewed as having multifarious motives that derive not only from economic exigencies but also from evolutionary, cultural, and spiritual factors deeply embedded in the human psyche. Although the consumption behavior of humans may be modeled as an academic exercise, such modeling exercises produce few practical or dependable policy implications.

Given a broader view of human nature, a spectrum of ends and means helps to place the academic terrain in context. Sciences that reduce the sphere of observation to physical and biological minutia provide insights to the *means* by which various human goals and objectives may be pursued. However, the meaning of life and the corresponding *ends* are beyond science to ascertain, and are often manifested in or interpreted through religion. Social sciences, interdisciplinary studies, and transdisciplinary approaches help to bridge the gap from reductionist science to meaningful lives; i.e., from means to ends. For example, physics is a study of ultimate means, theology is a study of ultimate ends, and social sciences including economics are studies of intermediate means (e.g., economic institutions) and ends (e.g., economic welfare).

Ecological economics explicitly and consciously encompasses a longer portion of the ends-means spectrum than neoclassical economics does. As ecological economics has arisen out of environmental concerns, the ecological expertise of its practitioners has been coupled with a closer analysis of all natural sciences of particular relevance to economic affairs, such as the laws of thermodynamics. In other words, ecological economics is concerned with ultimate means, virtually by definition, and how those ultimate means affect human economic prospects. Meanwhile, the normative stance of ecological economics requires a consideration of ultimate ends, including religious callings and needs. This is an ironic aspect of ecological economics to the extent that ecologists are often characterized as atheistic scholars with a purely evolutionary view of *Homo sapiens*. However, there are logical and faith-based reasons for linking ultimate means and ultimate ends in economic affairs, as revealed in the section below on the distribution of wealth.

3. Themes and Emphases in Ecological Economics

In conventional economics textbooks, economics is defined as "the allocation of scarce resources among competing end uses." Neoclassical economics tends to be focused on the issue of efficiency; i.e., efficient allocation of resources. Neoclassical economists acknowledge the scarcity of resources at any given point in time – it is due to scarcity that efficient allocation is called for – but do not often acknowledge long-run scarcity of resources. Neoclassical economists usually posit that innovation and new technology continuously push back the limits to production and consumption that are temporarily imposed by scarcity.

Ecological economics, on the other hand, emphasizes the scarce resources that must be allocated. Long-run limits are recognized as well as short-term limits, giving rise to the "scale" issue. This acknowledgment of long-run limits to growth leads to a strong concern about the distribution of wealth, too (as will be shown below). The scale issue and the distribution of wealth provide the context within which allocative efficiency is assessed.

3.1. The Scale Issue

As noted in the historical background, the importance of land as a factor of production has been unrecognized or downplayed in neoclassical economics. In economics and business textbooks the economy is often portrayed as a circular flow of money between firms and households. In the basic circular flow model, households provide labor for the firms, while firms possess the capital that, combined with labor, is required for the production of goods and services. Money passes from firms to households in the form of wages, which are eventually spent on the goods and services produced by firms.

In more detailed models of the circular flow, other aspects of the economy are introduced, either as "leakages" from the flow (e.g., savings) and "injections" into the flow (investment) or as other entities that occupy the circle. For example, a Keynesian version of the circular flow includes the government, which taxes firms and households, pays wages to some individuals, and purchases goods and services from firms. However, most circular flow models do not illuminate the extraction of natural resources used as inputs to the production process, much less the environment as the context in which the economy functions.

In ecological economics, the circular exchange between firms and households is acknowledged, but graphical models of the economy emphasize the context within which this exchange transpires. The economy with all its firms and individuals and government sectors is shown to exist within its containing, sustaining ecosystem. The ecosystem is shown to provide energy (primarily the solar energy required for photosynthesis and therefore agriculture) and the natural resources (such as water, timber, and minerals) that are required for the production of consumer goods and services and for the manufacturing of capital and infrastructure. As importantly, the ecosystem is shown to absorb the wastes and pollutants of the economic production process. With this graphical image of the economy in mind, the student proceeds with an awareness of the primacy of land as a source of economic inputs and the importance of the environment as a sink for pollutants.

This image also helps the student to recognize and appreciate the issue of "scale," which refers in ecological economics to the size of the economy relative to its containing, sustaining ecosystem. The concept of scale raises numerous analytical questions with increasingly important policy implications. The most pressing questions are: 1) What is the maximum sustainable scale? 2)

What is the optimum scale? Both of these questions may be asked at local, national, regional, or global levels.

Considerations of maximum sustainable scale are enlightened by the ecological literature pertaining to carrying capacity, which refers to the number of animals an ecosystem may support. For any species, carrying capacity is determined by a mix of welfare and decimating factors. For wildlife species, the welfare factors are those that comprise a species' habitat: food, water, cover, and space. Decimating factors include predators, diseases, and severe weather. Carrying capacity for the typical species of wildlife is expressed in terms of the number of individuals the ecosystem may support.

In ecological economics, the relevance of carrying capacity to *Homo sapiens* is highlighted. However, humans differ from other animal species with regard to the use or consumption of habitat components per individual. In fact, per capita consumption among humans varies by orders of magnitude. Therefore, a better metric (than numbers of humans) for expressing human carrying capacity is GDP, which is an indicator of human population and per capita consumption. In other words, GDP is a reasonably good indicator of the size of the human economy; i.e., the level of production and consumption of goods and services in the aggregate. As such, it is also a good starting point for determining the scale of the economy (i.e., size of the economy relative to the size of the ecosystem).

The fact that GDP is expressed in value units should not lead to the false conclusion that it is not a physical measure with ecological implications. GDP is a value-based aggregate of physical goods and services. A dollar's worth of X is a physical quantity thereof, and GDP is an aggregate index of physical quantities. The accuracy and precision with which GDP represents physical activity and throughput is an issue requiring further attention and research (see Section 5.2).

The scale issue encompasses all aspects of the economy/ecosystem relationship – pollution, crowding, climate stability, etc. – and one aspect that has received substantial attention is biodiversity conservation. Conservation biologists have contributed to ecological economics by describing the principles of ecology that are most relevant to the human/biodiversity relationship, such as niche breadth and competitive exclusion. For example, they have described how, due to the tremendous breadth of the human niche, which expands via new technology, the human economy grows at the competitive exclusion of nonhuman species in the aggregate. These and related principles have led professional, scientific societies such as The Wildlife Society and the American Society of Mammalogists to take policy positions on the "fundamental conflict" between economic growth and biodiversity conservation. The word "fundamental," in this context, indicates that the conflict is based upon principles of physics and ecology, and not mere observation.

Meanwhile, ecologists and economists have teamed up to describe, quantify, and estimate the economic value of "ecological services" provided by nonhuman species and other features of the natural environment. For example, many species are beneficial to the human economy because, during the courses of their life cycles, they incidentally pollinate wild and domestic plants that are valued by humans for food and fiber. When the fundamental conflict between economic growth and biodiversity conservation is recognized in tandem with the value of ecological services provided by nonhuman species, then economic growth is recognized not only as a threat to biodiversity but also as a threat to the continued functioning of the human economy.

Maximum sustainable scale, then, cannot be estimated without an understanding of: 1) the natural resource stocks and ecological services provided by nature, collectively referred to as "natural capital;" 2) how natural capital stocks and services are converted or used up in the process of economic growth; 3) to what extent natural capital is substitutable by human technology, and; 4) the prospects for human technology to progress in a manner and at a rate sufficient for finding, and putting into production, substitutes for natural capital. All four of these topics are highly complex, and ecological economists do not presume that humans will develop a thorough and accurate synthesis, espousing instead the "precautionary principle" in environmental and economic management. However, meaningful approaches to the assessment of scale have been developed to inform citizens and policy makers. An example is the "ecological footprint" concept, pioneered by William Rees and Mathis Wackernagel, which is used to demonstrate the amount of area required to support human economies. Ecological footprinting and related analyses have centered upon inventories of natural capital and the natural capital requirements of economic activity.

The ecological footprint literature has indicated that many national economies, as well as the global economy, are already operating beyond their maximum sustainable scale. For example, some estimates suggest that, if all humans on Earth consumed at the same level per capita as

Americans, it would take 23 Earth equivalents to sustain them. Globally, other estimates suggest that the level of per capita consumption at the dawn of the 21st century would require 4 Earth equivalents to be sustainable. According to these types of studies, humans have been able to consume at levels higher than those sustainable in the long run only because they have been using natural capital at a rate too fast for its replenishment or replacement; i.e., humans have been "liquidating" natural capital such as fossil fuels (especially petroleum).

Ecologists, too, have long recognized that species may exist for periods of time at populations that exceed long-run carrying capacity. However, in many such cases the result is a long-term reduction in carrying capacity, such as when an ungulate species decimates its food source and damages the soils, leading to erosion and the development of a different type of ecosystem that is not as supportive of the ungulate species.

Many neoclassical economists and others sometimes referred to as "technological optimists" have opined that the concept of carrying capacity does not apply to humans because, unlike other animals, humans are able to manipulate their environment and develop evermore efficient modes and methods of production. This belief has spawned a long-running argument about "limits to growth." In ecological economics, with some of its roots in the work of Georgescu-Roegen, the first two laws of thermodynamics are invoked to refute the notion of perpetual growth. The first law and its derivatives establish that neither energy nor matter may be created nor destroyed. From the second or "entropy law" comes the implication that it is impossible to achieve (much less exceed) 100% efficiency in an economic production process. Taken together, the laws of thermodynamics imply an absolute limit to economic growth. A related conclusion is that economic growth may not be continuously reconciled with environmental protection via technological progress and that apparent, intermediate reconciliation is often overestimated or nonexistent when all of the environmental impacts are accounted for.

For all of the complexities in determining maximum scale and maximum sustainable scale, limits to growth are becoming more evident, pervasive, and politically accepted. As a result, many ecological economists have turned their analytical focus to optimum scale. The starting point for assessing optimum scale is the "equimarginal principle of maximization," a staple concept in microeconomics that tells the firm to stop producing as the costs of production rise to match the revenue obtained from each new (or marginal) unit produced. Extending this logic to the economy at large, ecological economists recognize that the costs (in a broad sense) of growing an economy eventually exceed the benefits when the interests of society at large are considered. For the sake of maximizing social welfare, then, an economy should cease growing when the marginal disutility of growth has risen to the level of the marginal utility of growth. Economic growth beyond that point no longer serves as a net benefit to society; therefore, some ecological economists refer to it as "uneconomic growth." (There is some debate among ecological economists about the merits of using the phrase "uneconomic growth," especially in the policy arena, because "economic growth" is used in the vernacular and by conventional economists to refer to increasing production and consumption of goods and services, regardless of the net benefits to society.)

In ecological economics, most scholars concur that GDP is a reasonably good indicator of the size of an economy, but all are united in noting that GDP is not a good indicator of social welfare (thus the concept of uneconomic growth). Therefore, other metrics have been developed to provide clues about optimum scale. For example, in the 1980's Herman Daly and John B. Cobb developed an Index of Sustainable Economic Welfare (ISEW), which accounts not only for the monetary value of final goods and services (as with GDP), but also for the natural capital that has been liquidated in the economic process. Stemming from their work, Redefining Progress developed the Genuine Progress Indicator (GPI) in the 1990's. The GPI incorporates social factors of human welfare beyond purely economic factors. For numerous nations with the appropriate available data, when the GPI (or ISEW) is plotted against GDP, GPI has been stagnant or declining since the 1970's, even as GDP has continued to grow, suggesting growth beyond the optimum. Many other indicators in various stages of development may be used in similar assessments, such as the long-established Human Development Index or the more recent Gross National Happiness. The term "Gross National Happiness" was coined by the King of Bhutan in 1972, and the concept has received substantial theoretical and empirical analysis since the mid-1990's.

3.2 Distribution of Wealth

A useful way to view the distribution of wealth as an issue in ecological economics is to briefly consider how distribution is viewed in neoclassical economics, where the belief in unlimited economic growth conduces the attitude or philosophy that "a rising tide lifts all boats." In other words, because the scale issue does not exist in neoclassical economics, neoclassical economists assume that poverty may be solved by growing the economy ever-larger so that financial wealth may trickle down via employment opportunities or philanthropy. State-sponsored welfare programs are generally not condoned in neoclassical economics because they interfere with the free functioning and therefore the efficiency of market economies.

Conversely, heightened concern about the distribution of wealth follows naturally from the scale issue in ecological economics because limits to economic growth are emphasized. To borrow from the "rising tide" metaphor, the tide can only rise so far, and only a certain number of boats may be lifted. Given this knowledge, which is rooted in an understanding of ultimate means (matter and energy), the normative stance of ecological economics becomes paramount. Although evolution and natural selection are acknowledged and to some extent analyzed in ecological economics, ecological economists do not believe in leaving the prospects of the poor to the market. They recognize a broader suite of market failures than do neoclassical economists (see Section 3.3) and recognize that some factors of production are not conducive to efficient allocation via the market. Inefficient allocation may lead to or exacerbate distribution problems. Ecological economists agree with neoclassical economists about many other market failures and corrections that can be pursued with public policy, but they also believe in policies and programs to redistribute wealth if necessary for the purposes of distributive justice and the common good.

This leads to difficult policy decisions, because there are no scientific or mathematical formulae available to ascertain a just distribution of wealth. By definition, ethics are required even to acknowledge the concept of justice. Ultimately for most people, religion provides authority or at least guidance in constructing an ethical framework. Ecological economics includes some analysis of religious teachings with regard to economic justice. All major religions teach moderation and generosity in economic affairs, and warn of the spiritual perils of greed, riches, and luxury. Even simple reminders of such teachings help the public and policy makers with economic decision-making.

With regard to methods for analyzing the distribution of wealth, many of the concepts and tools used in the international development community are likewise used in ecological economics. For example, the Gini coefficient is used to determine the equality with which wealth is distributed among the populace, providing implications for public policy and international diplomacy. On the other hand, Pareto optimality (discussed further in the section on allocation of resources) is not deemed relevant to economic justice as it is in neoclassical economics.

International trade is one of the featured issues in ecological economics pertaining to the distribution of wealth. In neoclassical economics, free trade among nations is generally considered a desirable feature for the global economy. Free trade is considered a mechanism for the efficient allocation of resources and for facilitating global economic growth. This viewpoint is rooted in the principle of comparative advantage, developed by David Ricardo (1772-1823). A nation has a comparative advantage in the production of a good if its opportunity costs (as opposed to absolute costs) of producing the good are less than those in other nations. The implication for economic growth is that a higher level of global production may occur as nations specialize in the production of goods for which they have a comparative advantage.

In ecological economics, the principle of comparative advantage is neither denied nor deemed entirely applicable to the modern era, because one of the assumptions underlying the principle is that the factors of production do not move across national boundaries. By the latter decades of the 20th century, capital had become highly mobile and numerous mass international movements of labor had occurred, so the principle applies to a lesser degree than it did during the classical era of the 19th century. More importantly, however, with economic growth threatening to breach global ecological capacity, any phenomenon facilitating further growth is not necessarily deemed desirable in ecological economics, regardless of its conduciveness to allocative efficiency. Finally, voluminous and fast-paced international trade is seen to cause disruptions in the social fabric of nations and facilitates the concentration of wealth in nations with multiple comparative advantages. Advantageous terms of trade for nations with an industrial and institutional head start suggest that a laissez faire approach to free trade will produce an increasingly skewed macroeconomic distribution of wealth.

3.3 Allocation of Resources

"Allocation" in economics refers primarily to the use of "resources" in a general sense, meaning the factors of production. Allocation of factors may be analyzed or described macroeconomically, as in the proportions of land, labor, and capital that are used to produce the goods and services of a nation, but the primary concern in neoclassical economics is how the factors of production are allocated among firms and thenceforth commodities. Indeed, a common definition of economics is "the study of the allocation of resources among competing end uses," and many scholars would say that neoclassical economics is synonymous with microeconomics and that macroeconomics should be identified with another tradition, such as Keynesian economics. In any event, the primary measure of success in neoclassical economics (and among many Keynesians as well) is the efficient allocation of resources.

The phrase "competing end uses" requires some elaboration. With a focus on production, "competing end uses" connotes the productive activities of firms. For example, one firm may use oak logs to produce flooring, another to produce furniture. Flooring and furniture are end uses in the economic production process. With a focus on consumption, "competing end uses" emphasizes the choices of consumers. For example, one consumer may desire oak flooring while another desires oak furniture. It would not be efficient if most consumers wanted the supply of oak logs to take the form of furniture while firms used most of the logs to produce flooring. The quintessential finding and focus of neoclassical economics is that prices, as they evolve in a freely functioning market, dynamically conduce an optimum allocation of oak logs (and all other resources, for a given distribution of wealth and income among consumers).

Efficient allocation is important in ecological economics too, but the ecological foundation and ethical framework of ecological economics result in a different philosophy of allocation and different implications for allocative policy. First, the primacy of land among the factors of production is emphasized. Manufactured capital is not deemed substitutable for land, as it is to a large degree in neoclassical economics, but rather is recognized as deriving from the land, with energy expended by labor. Once it is manufactured, capital typically becomes complementary, not substitutable, to land in the production process. Second, efficiency is assessed in material or energetic terms more so than in financial terms. For example, it may be financially efficient for a firm to employ a particular ratio of capital:labor without being efficient in the use of material or energy. Third, because of the emphasis on scale, the macroeconomic aspect of efficiency is emphasized. A financially efficient mixture of inputs for the firm, or even a fiscally efficient mixture of government spending, may not be efficient or even feasible for the economy at large in material or energy terms.

All else equal – "ceteris paribus" in economics jargon – it is not efficient to employ a particular resource to produce a good or a service if another, more plentiful resource may be used instead. Prices help to provide information about the scarcity of resources; more plentiful resources are likely to go into production because the prices of those resources should be lower. For neoclassical economists, prices assure that no resources become so scarce as to cripple the attentive and competitive firm or economy, because new technologies and institutions are developed as prices send signals to firms and governments.

The faith in prices to obviate problematic resource shortages is less fundamental in ecological economics. All economists agree that various market "imperfections" result in faulty prices, but in addition, ecological economists emphasize that many natural resources and ecological services cannot be substituted for by capital or synthetic products, regardless how high prices might rise. Also, prices reflect conditions today, with little consideration of future generations. For example, oil prices during the 20th century did not reflect the energy shortages that would arise in the 21st century, much less the costs of global warming that ensued largely as a function of low oil (and other fossil fuel) prices.

Furthermore, certain goods and services (collectively referred to as "goods" in this section) do not have the characteristics required for efficient allocation in the market. These characteristics include rivalness and excludability. Rivalness is a natural property. A good is rival if one's consumption of it prevents its consumption by anyone else. For example, food is a rival good. Excludability is also a natural property, but, unlike rivalness, can only manifest in the context of a legal institution. A good is excludable if others may be prevented from using it. Excludability is required for property rights to be assigned, and some goods are more excludable than others. For example, non-migratory fisheries are more excludable than migratory fisheries. Regardless of how excludable a good may be, its *exclusion* must be enforced.

Rival goods are usually excludable to some degree. Many excludable goods and especially services are not rival, however. For example, singing in a concert hall may be enjoyed by one or many people. The singer, hall owner, and/or producer negotiate the level of exclusion and the price of tickets based upon the supply of singers (and concert halls) and the demand for singing.

Rivalness and excludability are required for prices to function as indicators of scarcity. Prices are particularly good indicators of scarcity for goods that are rival and excludable such as food, clothing, and housing. Conversely, prices are not particularly good indicators of scarcity for goods that are excludable but non-rival such as information and entertainment services. For goods that are not even excludable, prices can be neither demanded nor taken. Therefore, a free market in which prices arise as a function of supply and demand can result in the efficient allocation of rival resources, a less efficient allocation of non-rival but excludable resources, and no allocation of non-excludable resources. In other words, non-excludable resources must be provided, or maintained, through some other mechanism than the market.

The requirements of rivalness and excludability for efficient market allocation are particularly relevant in ecological economics because many natural resources are non-excludable or have low levels of excludability. Oceanic fisheries, large forests and rangelands, and remote mineral deposits are examples of natural resources that are rival but non-excludable or not readily excludable. They are susceptible to overuse by extractors who accrue the benefits without absorbing the full costs of overuse, resulting in prices that are too low for efficient allocation. This "tragedy of the commons," as described by Garrett Hardin in his classic paper of the same title, was one of the conceptual foundations of ecological economics (although the word "commons" was somewhat of a misnomer because traditional commons were often protected from overuse by complex social contracts and customs). The allocation of non-excludable resources that are even non-rival, such as the ozone layer, is even less sufficient. Protection of the ozone layer, crucial for human health and survival, required laws and international agreements to overrule the market forces that favored the use of chlorofluorocarbons as refrigerants.

Neoclassical economists have also acknowledged the tragedy of open-access, non-excludable resources and have emphasized that the cost to society of over-exploitation was an "externality" of the market, an externality that could be corrected for using various institutional arrangements. In ecological economics, it is agreed that some market externalities may be "internalized" to a degree with taxes, user fees, etc. However, in ecological economics such efforts are viewed as a somewhat Pyrrhic victory for the market, because they amount to the regulatory contrivances loathed in free market ideology. More importantly, however, the very term "externality" has symbolized to many ecological economists the problematic paradigm of neoclassical economics; i.e., that something falling outside of the market system is tangential to the focus of economics, which is the functioning of the market to allocate resources efficiently.

4. Policy Implications of Ecological Economics

Given the normative stance of ecological economics, public policy is viewed as an intermediate means along the ends-means spectrum (see Section 2.2). Given the themes and emphases of ecological economics, the policies of central concern are those that affect scale, distribution, and allocation. New policies are needed for sustainable scale, fair distribution, and efficient allocation, and reforms are needed for many existing policies that are unsustainable, unfair, and inefficient.

There are numerous theories, traditions, or schools of thought in public policy studies that are, to various degrees, applied in public policy. Most of these traditions have some type of economic basis or propensity. "Public choice theory," for example, is essentially the application of neoclassical economics, whereby the will of the public is freely and efficiently expressed through the choices individuals make in the market. In this tradition, public policy is designed to keep the market operating efficiently and, if necessary, to preclude government intervention. "Critical theory," with Marxist roots, is focused instead on the oppressive nature of political and economic powers. It calls for policy reforms as the needs for them are inevitably unveiled, and often these reforms interpose on market forces.

"Policy design theory" is a more recent effort, led by political scientists Anne Schneider and Helen Ingram, to meld the best traits of other public policy traditions. In policy design theory, a public policy is also judged by its adherence to and nurturing of democracy. As an integrating, synthesizing endeavor with a penultimate end of democracy, policy design theory is perhaps the tradition of public policy most conducive to the goals of ecological economics.

In their groundbreaking textbook, *Ecological Economics: Principles and Applications*, Herman Daly and Joshua Farley presented a set of six policy design principles. These include some standard, general-purpose principles, and several that reflect the approach and philosophy of ecological economics. The principles are, verbatim:

1. Economic policy always has more than one goal.
2. Policies should strive to attain the necessary degree of macro-control with the minimum sacrifice of micro-level freedom and variability.
3. Policies should leave a margin of error when dealing with the biophysical environment.

4. Policies must recognize that we always start from historically given initial conditions.
5. Policies must be able to adapt to changed conditions.
6. The domain of the policy-making unit must be congruent with the domain of the causes and effects of the problem with which the policy deals.

Each of these principles has a different level of importance or prominence in the pursuit of sustainable scale, equitable distribution, and efficient allocation.

4.1 Sustainable Scale

Ecological economics is often looked to for creative policy solutions to the problems of unsustainable scale and uneconomic growth (i.e., growth beyond optimal scale). Certainly there have been some original policy tools proposed in the ecological economics literature. However, the first and perhaps most important terrain in the policy arena, as it pertains to sustainable scale, is the myriad of already existing policies that conduce economic growth. These may be generally categorized as fiscal, monetary, and trade policies. Fiscal and trade policies generate the most attention in ecological economics. Not much is said in the ecological economics literature about reforming particular monetary policies, such as money supplies and interest rates, presumably because the proper reforms for sustainable scale are too obvious, and also because the challenge is quite daunting politically. Monetary authorities are expected to cut interest rates and increase money supplies to stimulate "sluggish" economies. However, if an economy has grown beyond optimal scale, and especially beyond maximum sustainable scale, monetary policy to stimulate economic growth does more societal harm than good. In this context, higher interest rates and tighter money supplies are appropriate. As of the first decade of the 21st century, though, ecological economics was not known widely enough in public and policy-making circles to precipitate a serious dialog about monetary policy toward a steady state economy. Monetary authorities typically favor higher interest rates and restrictive money supplies only when inflation threatens.

Economists (of all persuasions) also understand that monetary policy has limited effects. For example, when an economy is operating at full capacity, lowering interest rates and flooding the economy with money will only result in inflation. Similarly, as economic capacity diminishes due to the liquidation of natural capital (i.e., as limits to growth are reached) the economy must become "sluggish" and will almost certainly be forced to contract in the wake of major and global supply shocks such as Peak Oil (i.e., the peak on global per capita oil production). No amount of monetary tinkering can change this biophysical reality.

If a polity is determined to have economic growth, however, the monetary authority may "pull out all the stops" and, more importantly, fiscal policy too will be designed for growth. Taxes are likely to be lessened, with the hope that consumers will then spend more and stimulate the economy. Budgets will be reallocated in a manner also designed to stimulate the economy. An early 21st century example is the subsidizing of corn farming to increase the production of ethanol, a hoped-for alternative to petroleum as a primary energy source for economic growth.

These standard, traditional, expected responses of fiscal and monetary policy authorities are not consistent with ecological economics and the six policy design principles presented above. Most ecological economists believe that the global economy and many national economies are beyond maximum sustainable scale and probably far beyond optimum scale. Therefore, the ecologically economic approach would be to readjust fiscal and monetary levers downward. As yet, however, this type of policy reform is not politically feasible, which may explain to a large extent why the ecological economics literature is not replete with such policy recommendations. This also points to the primacy of identifying the appropriate policy *goal*, in contrast to particular policies. To some degree this is an issue of semantics because the formal acknowledgement of a policy goal may itself be deemed a policy. Such is the case, for example, with the U.S. Full Employment Act. When it was originally passed in 1946, full employment was the goal, for which the Full Employment Act established a programmatic approach; i.e., a policy or set of policy tools for achieving full employment. But full employment itself is a policy of the United States.

This example is especially relevant to sustainable scale, because the Full Employment Act is also perhaps the most codified manifestation of the general policy goal of economic growth in the United States. Although the number one goal of the Full Employment Act is full employment, it was and is assumed that the American population would grow. Therefore, ceteris paribus, a policy of full employment is equivalent to a policy of economic growth.

However, in the United States and most other nations, the expectation is that each generation will have a higher quality of life, especially in material terms. This is not codified, as is full employment in the United States, but it permeates public policy. Monetary authorities, for example, speak as often about their efforts to promote economic growth as to prevent unemployment or inflation. Also, in the United States, economic growth is part of the mission for at least 4 federal agencies beyond the Federal Reserve (the monetary authority). With all of the formal and less formal government policies and programs for economic growth, one may surmise that economic growth is the number one domestic policy goal of the United States and many other nations, and perhaps of the international governing community too (e.g., OECD, NAFTA signatories, World Bank, International Monetary Fund, etc.).

The linkage with full employment points to another crucial political issue for achieving sustainable scale: population size. Although an economy may grow beyond optimal and maximum sustainable scale either via population or per capita production and consumption, in one important sense overpopulation is the most fundamental problem to solve. Humans require a minimum amount of consumption to exist, such that continuous population growth must eventually lead to the breaching of carrying capacity. Conversely, per capita consumption may increase, at least in theory, without an inevitable increase in the global ecological footprint, if population is decreasing simultaneously. Neither population nor per capita consumption can increase perpetually, and to the extent that full employment remains a high priority, population is the more crucial parameter to stabilize. With a growing population, movement from economic growth to a steady state economy will entail some level of unemployment. The politics of advancing a steady state economy in this context are exceptionally daunting.

Summarizing to this point, sustainable scale entails replacing national and international goals of economic growth with the goal of a steady state economy at the optimal scale. This means that the policy of economic growth must be replaced with the policy of a steady state economy, and the policy complex designed to facilitate economic growth must be reformed to facilitate a steady state economy.

Reforming existing policies is a necessary but probably insufficient condition for establishing a steady state economy. New policies will almost surely be required, including policies designed to help with stabilizing population, per capita production, per capita consumption, throughput, and natural capital stocks. The most draconian approach in all cases is direct regulation, whereby the state imposes behavioral and commercial limits. Direct regulation is socially unpalatable and politically infeasible in most nations; otherwise it could be highly effective.

In addition to direct regulation, Pigouvian taxes and subsidies may be designed to contribute to sustainable scale. What distinguishes Pigouvian policies from other taxes and subsidies is their focus (after Arthur C. Pigou, 1877-1959) on correcting for market failures. This makes them palatable to most economists, and useful for social justice as well. Particular Pigouvian instruments may contribute substantially to sustainable scale, too. For example, if polluters are taxed the full social cost of the pollution, the rate of the pollution will decrease.

The most distinctive form of policy with regard to sustainable scale is the cap-and-trade policy, which also combines several of the policy design principles listed above. A cap-and-trade policy (or policy mechanism) may be effectively applied to most stocks of natural capital and to many pollutants. The relevance to scale is exhibited by the word "cap." When the use of a material or energy source that is integral to the economy is capped, the cap puts up a de facto sideboard to economic growth. The clearest example is with greenhouse gas emissions, especially from the combustion of fossil fuels. The global economy is primarily fossil-fueled, with petroleum constituting the primary transport fuel and coal a significant electric power fuel. Capping greenhouse gas emissions in this context is tantamount to capping economic growth.

The primary objective of policy makers in capping, or attempting to cap, greenhouse gas emissions is not to stop economic growth, but rather to protect the atmosphere and prevent catastrophic levels of global warming. Yet the predictable economic dampening effects of a strict cap on greenhouse gas emissions has prevented some of the wealthiest nations from participating in international agreements to lower greenhouse gas emissions. This experience demonstrates the primacy of macroeconomic policy goals in the policy arena.

Theoretically, starting from the perspective of ecological economics, one could prescribe a cap on greenhouse gas emissions explicitly for scale-limiting purposes. However, this would only be feasible if the international community agreed, consistent with the tenets and findings of ecological economics, that global economic growth was no longer an appropriate goal. Then the level at which the greenhouse gas emissions (or other ecologically relevant) cap would be set would be informed by policy design principles 3-5 (above). Pursuant to principle 3, a precautionary approach is called for, so that any benefit of the doubt would be applied to environmental protection and future generations. Pursuant to principle 4, however, the cap would be applied gradually to avoid shocking the economic system. In an age of environmental crisis, the principle or necessity of gradualism indicates the need to accept the steady state economy as a policy goal quickly enough, while (or assuming) there is still time for gradual policy adjustments.

Pursuant to principle 5, policies to cap throughput must be designed with flexibility so, as limits to growth and optimum scale become more apparent, caps can be readjusted. Because many throughput issues are global in nature, international policy entities and instruments are required pursuant to principle 6. For example, The Kyoto Protocol was an early attempt at capping the rates of greenhouse gas emissions via global convention.

Principle 2 calls for the minimum sacrifice of micro-level freedom. Cap-and-trade policies meet this principle better than direct regulations because firms are free to trade throughput permits within the limits established by the cap. Markets are established, permits are allocated among firms, and thenceforth some of the allocative advantages of laissez faire markets are engaged. Other advantages are not, however. For example, whereas a laissez faire market requires no government interference and expenditure, a cap-and-trade system is essentially a government-established system, with rules enforced by the government. This reflects the fact that natural capital is typically not wholly or readily rival and excludable. However, the throughput permits are entirely rival and excludable, and therefore tend to be allocated efficiently among the firms.

A cap-and-trade policy, then, is a legitimate compromise between laissez faire and central planning, and most if not all public policy traditions will appreciate various aspects of it. The cap-and-trade policy is emblematic of policy design principle 2, as it is designed to attain the necessary degree of macro-control with the minimum sacrifice of micro-level freedom.

4.2 Fair Distribution

In ecological economics, the goal of fair distribution cannot be effectively pursued unless the goal of sustainable scale is already achieved or is being achieved. If sustainable scale is not a policy goal, and economic growth is occurring beyond maximum sustainable scale and remains a goal of the state, then efforts toward fair distribution are certain to fail. As limits to growth are breached, history shows that conflict invariably ensues and the victors claim the natural resources, including the land itself. Peaceful and equitable coexistence requires a social contract in which citizens agree to live sustainably, as a society, and to share, within reason, natural resources and other wealth. In ecological economics, this social contract would be manifest in caps on income and wealth, minimum income, and the distribution of returns from the factors of production, especially natural capital.

Ecological economists tend to be more aligned with "Georgists" (modern-day followers of Henry George) than are neoclassical economists. George and other classical economists made the compelling point that, unlike labor or capital stocks, the land cannot grow. While labor and capital stocks proliferate and become more prominent relative to land, the value of land increases. In other words, the landowner becomes wealthier by virtue of others' toil. Georgists and many ecological economists believe that the unearned rents of landowners should enter into the commonwealth instead.

Socialists may even advocate state-holding of all land. Ecological economists tend to advocate a balance of public and private lands, as long as firms are not subsidized to extract natural capital from public lands and landowners are taxed unearned rents. Taxing unearned rents is advanced as a highly practical approach to fair distribution because systems of land taxing already exist. It is the rationale and formulae that would be transformed by ecological economics, more than the institutional arrangements of taxing.

The rationale for capping income and wealth flows directly from the scale issue to the distribution issue. If the global economy is at maximum sustainable scale, the acquisition of more income or wealth by an individual entails the breaching of long-term carrying capacity, unless an equivalent amount of income or wealth is taken away from someone else. Especially if that individual were already very wealthy, it would run against the ethical stance of ecological economics for he or she to jeopardize the environment, fellow citizens, and future generations by consuming at an even higher and unsustainable level.

On the other side of the same ethical coin is the logic for capping or redistributing income and wealth. Given a global economy exceeding its maximum sustainable scale, the only ethical and ecologically economic approach to alleviating poverty while moving closer to sustainable scale is the capping of income and wealth, with pre-existing excess used to alleviate poverty. Precisely at what level to cap income or wealth is a matter to be determined, ideally in a democratic manner (according to policy design theory), whereby the majority of citizens understand the need for caps on throughput and therefore caps on income, and support the goals of sustainability and social justice. Presumably a gradualist approach would entail formal but voluntary capping, followed if necessary by imposed capping. Data pertaining to the existing scale of the economy, a range of optimal scales, and the ecological footprints associated with different levels of income and wealth would be necessary for determining appropriate capping levels.

At the other end of the distributional policy spectrum is minimum income. A minimum income policy has logical and ethical foundations pertaining to scale and distribution. Logically, impoverished individuals are highly unlikely to prioritize environmental considerations, which is crucial for establishing sustainable scale. For example, landless, unemployed peasants may resort to poaching timber from public lands. Poor people typically have been victims of circumstance rather than lazy, and the ethical response is to help them without jeopardizing the environment and future generations. In other words, in a full world economy, the logical and ethical approach is to distribute a minimum income to the needy, procured from the over-capped excesses of the wealthy. This approach combines a steady state economy with a fairer distribution of wealth.

4.3 Efficient Allocation

Efficient allocation, the summum bonum of neoclassical economics, is de-prioritized in ecological economics, but only relative to the urgent, first-order needs of sustainable scale and equitable distribution. Yet efficient allocation is important in ecological economics from the normative perspective of reducing waste, and from the macroeconomic perspective that efficiency allows for higher sustainable scale. In addition, a key distinction between conventional economics and ecological economics is that, in ecological economics, the prospects for *technical* efficiency are recognized as limited by the second law of thermodynamics.

Because ecological economists acknowledge that the market is often a reasonably efficient mechanism for allocating private (rival and excludable) goods, they tend to focus on the estimation of economic values of non-market or public natural capital and ecosystem services. Such estimation exercises help to educate the public and policy makers about the opportunity costs of private goods production and consumption that are incurred by society as natural capital and ecosystem services are eroded. In some cases the estimated values can also be used in the development of Pigouvian taxes and subsidies (see Section 4.1). They also assist decision-makers in cost-benefit exercises. A widely cited example is the decision of New York metropolitan officials to acquire and protect portions of the Catskill Mountains. In 1997 the city of New York had the choice of installing a water filtration plant at a cost of $4–8 billion, with $250-300 million per year in operating costs, or to invest approximately $1.5 billion in the natural capital of the Catskills, maintaining the already existing ecosystem service of water filtration. New York opted for the latter.

Basic methods for estimating the values of natural capital and ecosystem services include:

1. Market Price Method. Many ecosystem goods or services are bought and sold in commercial markets. Although externalities exist, market prices provide a starting point in estimating the value of related natural capital and ecosystem services.
2. Productivity Method. Economic values may be estimated for intermediate ecosystem goods or services that contribute to the production of commercially marketed final goods.
3. Hedonic Pricing Method. Economic values may be estimated for ecosystem goods or services that directly affect prices of some other marketed good or service.
4. Travel Cost Method. Based on the assumption that the value of a recreational site is reflected in how much people are willing to pay to visit the site, economic values associated with ecosystems or parcels of land that are used for recreation.
5. Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods. When an ecosystem is protected from economic or other disruptive activities, damage costs are avoided, as are the costs of replacing ecosystem goods and services or of providing substitute goods and services.
6. Contingent Valuation Method. Economic values for virtually anything may be estimated contingent upon certain hypothetical scenarios. For example, people may be asked how much they are willing to pay for the protection of an ecosystem or certain of its natural capital stocks or ecosystem services.
7. Benefit Transfer Method. Estimates economic values by "transferring" (or extrapolating) existing estimates obtained from studies already completed in other areas.

None of the above methods are unique to ecological economics; all have been described in environmental economics, or the application of neoclassical economics to environmental issues.

The contribution of ecological economics to the use of these methods is primarily in the deeper understanding of the components, structures, and functions of ecosystems that need to be evaluated in economic accounting and decision-making. There have been many collaborative efforts between ecological and environmental economists in estimating values of natural capital and ecosystem services.

5. Future Directions and Challenges for Ecological Economics

Ecological economics is now somewhat established in academia but remains a mere infant in policy circles. Because it embraced a diversity of perspectives and methods from the beginning, its emphases and tendencies have always been subject to challenges and have varied from one region to another. For example, the European tradition of ecological economics has emphasized the distribution of wealth to a relatively greater degree than the American tradition, which conversely has emphasized sustainable scale and, especially since the 1990's, efficient allocation of natural capital. However, the first decade of the 21st century ushered in dramatic social, political, ecological, and economic changes. These ongoing developments simultaneously empower and challenge ecological economics, and will affect the course it takes for the remainder of the 21st century.

5.1 Reinforcing the Primacy of Sustainable Scale

One challenge for ecological economics is to revisit and reinforce the primacy of sustainable scale as the most distinctive and original aspect of ecological economics. Prioritizing sustainable scale constitutes the "Dalyist" tradition of ecological economics (see Section 1). Although sustainable scale is often listed as the highest priority in ecological economics textbooks or overviews, the Dalyist tradition has been overshadowed in academia and in practice by exercises in which the value of natural capital and ecosystem services are estimated in monetary terms, often in great econometric detail, sometimes with little ecological grounding, and almost always with little macroeconomic context. This is evident in the literature at large, and even in the flagship journal *Ecological Economics*.

The emphasis on natural capital valuation has resulted from at least three phenomena. First, sustainable scale will clearly entail macroeconomic policy reform, including the introduction of new policy tools and the adjustment of existing policies, and such policy reform is a daunting challenge. While widespread agreement exists on the importance of "getting the prices right" with ecologically informed microeconomics, replacing the macroeconomic goal of growth with the goal of a steady state economy entails a veritable paradigm shift on the part of conventional economists, policy makers, and society at large. Fiscal, monetary, and trade policies are crafted at high levels of government and are affected by powerful corporate interest groups, or what is sometimes called "the corporatocracy" to indicate the concerted nature of corporate influence in economic policy making. Using a concept from political science, some observers refer to an "iron triangle" of corporations, politicians endeared to corporations, and influential economists who are hired by corporations or appointed by politicians. This tri-partite network surrounds and pervades the macroeconomic policy arena, making it extremely difficult to access or succeed in. Monetary policy in the United States, for example, is developed and implemented by a central bank, the Federal Reserve System ("the Fed"). The Fed's board members, who typically come from and return to prestigious posts in academic bastions of neoclassical economics, are appointed by the President of the United States and serve 14-year terms. In other words, the conventional, neoclassical approach to monetary policy will be difficult and time-consuming to supplant, and many ecological economists view the prospect of reform as impractical to undertake at this point in history.

Second, as environmental concerns intensify, more neoclassical economists are focusing on environmental issues, and even joining ecological economics organizations such as the International Society for Ecological Economics. Given the fact that there are far more neoclassical economists than ecological economists, the ratio of neoclassical economists to ecological economists in the "ecological economics" community has been increasing. Their education and training have prepared them to ascertain and analyze prices, and to publish papers thereon, but not usually to ascertain and analyze the ecological limits to economic growth.

Third, funders of research tend to be more interested in natural capital valuation than in sustainable scale. This is partly a function of the earlier observation that macroeconomic policy reform is too daunting to attract participants, including funders who often want to see clear and relatively quick results from their grants. There is the additional reason that much macroeconomic policy – especially monetary policy – is handled almost exclusively at national levels, by relatively few officials. Fiscal policy, on the other hand, is handled by numerous officials in local, regional, and national authorities, but fiscal policy is often microeconomic in nature (for example, taxing a type of good), although it can be macroeconomic (for example, establishing rates for income taxes). While the primary goals of conventional monetary policy are stimulating growth and preventing inflation, the goals of fiscal policy are much more diverse and often entail pricing mechanisms or adjustments. For non-market goods and services, such as ecosystem services, economic values must first be estimated to enable the use of pricing mechanisms. The volume and diversity of issues requiring valuation exercises conduces a condition in which neoclassically (or microeconomically) trained economists outnumber the ecologically (and macroeconomically) trained economists, contributing to the prominence of valuation exercises in ecological economics.

Given these reasons for the emphasis on natural capital valuation in ecological economics, the ecological economics community faces the question: Is such an emphasis a problem? If so, how may the problem be solved? Concerns are often expressed within the ecological economics community about the emphasis of natural capital valuation, so there must be a real or perceived problem. Perhaps the most common concern is that, by focusing on natural capital valuation, ecological economics becomes little more than environmental economics; i.e., an extension of neoclassical economics. Given that ecological economics arose from the realization that neoclassical economics was inadequate for illuminating sustainability challenges and helping to solve them, a merger of neoclassical and ecological economics may be considered a weakening compromise. This concern has led some of the early participants in ecological economics to distance themselves and/or establish other, mostly informal alternatives to neoclassical economics. For example, some distinguish their research as "biophysical" economics to indicate the prominence of natural sciences in their work.

On the other hand, natural capital valuation has helped the ecological economics community to become more immediately relevant to the conventional economics community and to policy makers faced with difficult decisions about allocating natural resources. The relative ease of natural capital valuation exercises and the political and economic support for such studies has also resulted in a plethora of opportunities for graduate students to engage in ecological economics, and presumably many of these students will graduate further into ecological macroeconomics and issues of economic justice. Valuation studies have been reported in numerous journals, helping to familiarize diverse scholars and professionals with at least the allocation aspect of ecological economics.

To summarize without casting judgment on the merits to date of natural capital valuation relative to sustainable scale and distributional investigations, clearly the emphasis on natural capital valuation has been at least somewhat problematic for the ecological economics community. One way to lessen the problem is by providing more detail on the macroeconomic context of valuation studies. In journal articles, the basic concepts of limits to growth and sustainable scale are usually highly relevant to the contexts of valuation scenarios and may be described in introductions and conclusions or discussion sections. For example, the economic value of biodiversity has become a research topic because biodiversity has been lost as a function of economic growth. Instead of delving immediately into descriptive details of particular species and ecosystems, and then presenting valuation methodologies, authors can briefly describe the aggregate (macroeconomic) pressures that led to the scarcity of the species or ecosystems in the first place. Similarly, in the conclusions of such articles, authors may duly note that getting the prices right is indeed helpful for efficiently allocating biodiversity, but that ultimately, if biodiversity is to be conserved, a steady state economy will be required.

A re-emphasis on sustainable scale, as well as more attention to fair distribution of wealth, may also be instituted in academia via program development, curriculum development, faculty qualifications, graduate student examinations, and community service. Government agencies and non-governmental organizations with conservation interests may also contribute to these emphases via program development, staff qualifications and training, and public education campaigns.

5.2 Clarifying the Ecological Implications of Money Volumes and Flows

As with any academic endeavor, ecological economics raises as many questions as it answers, and it is beyond the current scope to list many such questions. However, one question stands out as exceptionally relevant and important to answer soon, given the scenario(s) of ecological unsustainability developing concurrently with financial crises. The question is, "What is the nature of money?" in particularly ecological terms, or in terms that are most relevant to sustainable scale as well as financial solvency.

It has been posited by some that volumes or flows of real (inflation-adjusted) money are reliable indicators of scale. If this is so, then real GDP, for example, could be used by a society to gauge its sustainability. In other words, actual GDP would serve as a surrogate for the ecological footprint, and estimates of maximum and optimum scale could also be expressed in GDP terms, greatly simplifying the application of ecological economics to macroeconomic policymaking.

Nevertheless, there is considerable disagreement among ecological economists about the ecological nature of money. Some think that money cannot serve as an indicator of scale because prices are determined by demand as well as supply, and demand is a psychic function as opposed to an ecological function. Also, because different goods and services enter the market as new technologies are developed, the ratio of throughput to money may change over time, preventing policy makers from equating money volumes and flows from environmental impact.

The possibility of using money volumes and flows as indicators of scale warrants a concerted investigative effort in ecological economics. A clear and convincing demonstration that standard measurements of money volumes or flows may be used to assess scale could become one of the most important academic accomplishments of the 21st century. It would help to guide the formulation of macroeconomic policy goals, the administration of monetary and banking policies, and the expectations of international financial institutions and capital markets.

5.3 Conceivable Need for De-Growth

With an emphasis on sustainable scale, scholars of the Dalyist tradition suggested for decades that societies and polities undertake conscious planning for steady state economies so that the ravages of "overshoot" could have been avoided. Total avoidance no longer seems feasible. Peak Oil, climate change, the ecological footprinting literature, and financial crises suggest that the global economy has already caused grave ecological and economic damage and is substantially beyond long-term sustainable scale. In the context of large pre-existing ecological footprints of wealthy nations such as the United States, rapid economic growth in 21st century China and India appears to assure that vast regional economies and the global economy will suffer a protracted and deep recession. However, to the extent that economic growth may be consciously slowed by determined polities (including citizens as conscientious consumers in addition to policy makers working toward economic policy reform), overshoot damages may be lessened. It is in this context that some scholars and activists have begun to advocate for immediate and long-lasting economic "de-growth." An example is the movement for La Décroissance (The Decline) in western Europe.

Some of the more ardent advocates of economic de-growth have gone as far as critiquing the goal of a steady state economy as already anachronistic and insufficient for ecological and economic sustainability in the 21st century. This critique has its logical merits, as briefly indicated in the preceding paragraph. However, in the long-run, a de-growing economy is no more sustainable than a growing one.

The challenge for ecological economics, then, is to incorporate de-growth research and policy implications without losing sight of the long-term goal of a steady state economy. Some questions for researchers to explore include: 1) How far beyond carrying capacity is the economy? "The economy" may be the global economy or an economy at any geographic scale, such as a state or province. (For less-than-global economies, scale may be analyzed with respect to the respective endowments of natural resources.) 2) What is the long-run maximum sustainable scale of the economy? 3) What is the optimum scale? 4) When maximum sustainable scale is breached, how much is carrying capacity compromised and how quickly must an economy recede to avoid further compromising of carrying capacity? 5) With or without breaching, how will maximum and optimum scales change over time due to natural and anthropogenic forces? 6) What types of policies and institutions are required for de-growth and for the maintenance of steady state economies?

6. Conclusion

In the context of climate change, Peak Oil, financial meltdowns, resource conflicts, and other indications of environmental and economic crisis, economics is at a crossroads. Citizens, economists, and policy makers have numerous choices among economic pathways of thought. The conventional choice is neoclassical economics with its focus on the efficient allocation of resources. Yet historical perspective and scientific analysis strongly suggest that the path paved by neoclassical economics, regardless of how efficiently traversed, does not lead from crisis to sustainability.

Ecological economics was developed partly as a response to the real and perceived shortcomings of neoclassical economics. In ecological economics, limits to economic growth are recognized as stemming directly from laws of thermodynamics and principles of ecology. A key concept is that efficiency is itself limited, so that perpetually increasing efficiency is not an alternative and may not overcome limits to economic growth.

Limits to growth call for expanding the theory and practice of economics to include the issue of scale, or the size of the economy relative to its containing, sustaining ecosystem. This leads in turn to addressing the distribution of wealth. If the tide of the global economy can rise only so far, then only a limited fleet may be accommodated. In ecological economics, economic justice is not about trying to defy the laws of physics by raising the tide past the realm of possibility, but rather ensuring that tiny, law-abiding boats are not capsized in the wakes of hulking luxury liners.

Ecological economics faces numerous challenges stemming primarily from the political difficulties entailed by a critical analysis of economic growth as a policy goal. As with any endeavor that develops in academia prior to manifesting in society, there are also numerous theoretical and methodological issues to be developed, and the list of such issues is likely to lengthen as the body of research expands. To the extent that ecological economics research is conducted, transmitted, and understood by publics and polities, it is likely to have major effects on consumer behavior, economic policy, and international diplomacy.

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Glossary

Allocation of resources	: Delivery and procurement of real estate, natural resources, labor, manufactured capital, product inventories, and finances to or by producers of goods and services.
Carrying capacity	: Amount supportable; typically used to indicate the number of animals that an area or ecosystem may support; see Maximum sustainable scale for application to human economy.
Competitive exclusion	: Ecological principle establishing that no two species may occupy the same niche, and by extension that species with overlapping niches exclude each other at the margins; applicable to producers in human economy.
Distribution of wealth	: Delivery or possession patterns of material assets including stocks, funds, goods and services.
Ecological economics	: A transdisciplinary endeavor in which practitioners incorporate and synthesize principles and concepts from natural sciences, most notably physics and ecology, and social sciences toward the end of understanding economic affairs and effecting sustainable, fair, and efficient economic outcomes.
Economic development	: Modification of economic production and consumption modes and patterns; implies qualitative improvement such as increased happiness.
Economic growth	: Increasing production and consumption of goods and services in the aggregate as indicated by increasing GDP; entails increasing population and/or per capita consumption; entails increasing throughput.
Economic de-growth	: Decreasing production and consumption of goods and services in the aggregate as indicated by decreasing GDP; entails decreasing population and/or per capita consumption; entails decreasing throughput.

Economy of nature : Species and their processes of production and allocation of resources; typically refers primarily to nonhuman species; roughly synonymous with ecology.

Environmental Kuznets curve : Hypothesis that economic growth initially causes environmental problems that are solved after the economy grows (especially in per capita terms) beyond a threshold level; applicable in certain microeconomic scenarios (such as specific pollutants) and not in macroeconomic scenarios (such as biodiversity conservation).

Factors of production : Energy and materials, primarily, that are required for the production of goods and services; land (including physical space and natural capital), labor, and manufactured capital; see also "Allocation of resources." Aspects of human development (e.g., education) and institutional arrangements are sometimes also classified as factors of production.

Maximum sustainable scale : Largest economy that may persist for an extended period of time given ecological constraints.

Natural capital : Ecosystem components, structures, and functions that are used directly in the economic production process or may otherwise contribute to economic welfare; includes all natural resources.

Natural capital fund : Ecosystem components, structures, and functions that do or may yield services contributing to economic welfare. (For example, forests yield water filtration services.)

Natural capital stock : Ecosystem components that do or may yield flows contributing to economic welfare. (For example, forests yield timber.)

Niche breadth : Range of ecological resources used by a species and the variety of methods and modes with which the species uses those resources; range of factors of production used by a producer and the variety of methods and modes with which the producer uses those resources.

Optimum scale : The size of an economy at which the marginal benefits to society of economic growth equal the marginal costs, where benefits and costs include market goods and services and non-market conditions; larger than zero economic activity and less than maximum sustainable scale.

Producers : Occupants of foundational trophic level in an economy; plants in economy of nature and farmers in ecological economics; more generally in conventional economics, proprietors that transform factors of production into goods and services.

Scale : Size of an economy relative to its containing, sustaining ecosystem; magnitude of geographic area.

Steady state economy : A stable or mildly fluctuating population producing and consuming a stable or mildly fluctuating volume of goods and services; entails stable or mildly fluctuating throughput; indicated by stable or mildly fluctuating GDP.

Sustainable economy : A steady state economy within the carrying capacity of its ecosystem; an economy that neither grows beyond carrying capacity nor recedes to non-existence.

Sustainable scale : Size at which an economy may persist for an extended period of time given the carrying capacity of its ecosystem.

Technical efficiency : Ratio of usable product to inputs required for production; synonymous with productivity. (Increasing technical efficiency is synonymous with more output per unit input and, ceteris paribus, increasing profits for the producer.)

Technological progress : Invention and innovation corresponding with increased technical efficiency.

Throughput : Physical inputs to the economic production process and physical outputs therefrom, including wastes or pollutants.

Trophic levels : Categories of species or economic sectors grouped in relation to energy flows; simplest breakdown is producers and consumers.

Uneconomic growth : Growth of an economy beyond optimum scale, with marginal costs of growth exceeding marginal benefits of growth to society, where costs and benefits include market goods and services and non-market conditions.

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Biographical Sketch

Brian Czech was born in Green Bay, Wisconsin, USA, on March 25, 1960. He has a B.S. in wildlife ecology from the University of Wisconsin-Madison, an M.S. in wildlife science from the University of Washington, and a Ph.D. in renewable natural resources with a minor in political science from the University of Arizona. He developed a focus on ecological economics during his Ph.D. research.
He is the founding president of the Center for the Advancement of the Steady State Economy (CASSE), a non-profit organization based in Arlington, Virginia. He is also a visiting professor in the National Capitol Region of Virginia Tech, Falls Church, where he teaches ecological economics, and is a certified wildlife biologist with 20 years of public service. Czech has helped to develop conservation policies and programs for tribal governments and at the national level. He is also the author of *Shoveling Fuel for a Runaway Train* and (with Paul R. Krausman) *The Endangered Species Act: History, Conservation Biology, and Public Policy*. As of 2008 he had more than 50 articles published in over 20 scientific and professional journals, indicating the transdisciplinary nature of his work. His emphases have been the ecological macroeconomics of biodiversity conservation, using theoretical and empirical approaches, and the political economy of environmental protection.
Dr. Czech has been an active member of numerous professional societies, including The Wildlife Society, American Fisheries Society, Society for Conservation Biology, International Society for Ecological Economics, and U.S. Society for Ecological Economics.

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