GSA Office of Governmentwide Policy

section 2

APPENDIX

The New Sustainable Frontier

PRINCIPLES OF SUSTAINABLE DEVELOPMENT

September 2009

economic decision–making

Ecological and Traditional Economics

Economic Literature Review

Additional Readings in Economics

ecological + traditional economics

Traditional Economic Theory: An Overview

Ecological Economics: History & Theory

Translating Theory Into Practice: Tools & Applications

traditional economic theory: an overview

Traditional or general economics studies the allocation of limited resources among competing ends. Its main concern is efficiency.[1] Although many economic disciplines have emerged throughout history, here the Neoclassical School of thought is described, as it is currently the dominant approach and much of ecological economics literature is written in opposition to its principles. Although ecological economics exists in part to address failures with neoclassical economic theory, most tenants of micro and macro economic theory are useful to all economists as they accurately describe the relationships among various factors that produce certain economic outcomes. This overview should allow readers unfamiliar with economic theory to understand the principles of ecological economics discussed in the GSA publication, "The New Sustainable Frontier."

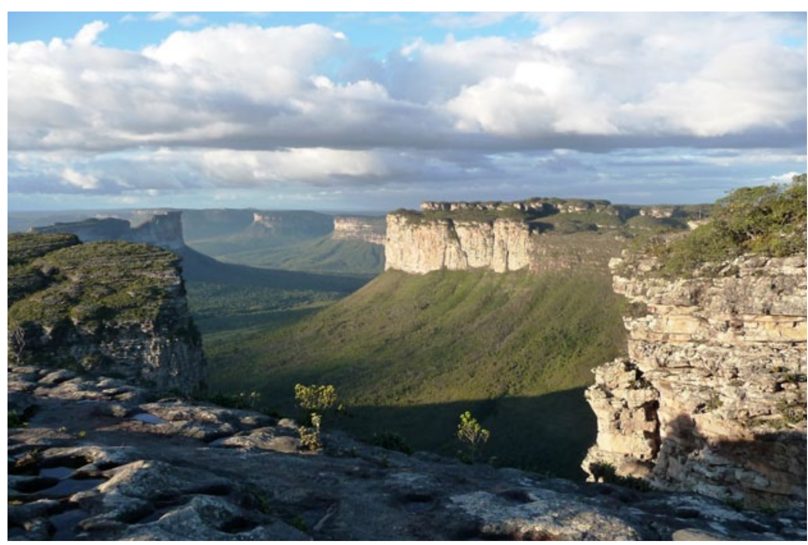
Microeconomics

Microeconomics studies resource allocation and decision-making at the level of the individual consumer, household or firm. It is concerned with how and why these entities make decisions about what to purchase, how much to produce, and what price to charge.

Supply and Demand

Decisions regarding how much of a commodity to produce, what price should be charged, or how much of it should be purchased can be made using a supply and demand model.[2] With price on the y axis and quantity on the x axis, demand is represented by a line with a negative slope (demand curve), reflecting

Right: "Chapada Diamantina National Park, Salvador, Brazil." Photo Credit: Jonathan Herz



the fact that, for most goods and services, consumer demand for a commodity falls as the price rises.

Supply is typically represented line with a positive slope (supply curve), showing that the firm's willingness to supply a commodity increases as the price rises. This is often called the partial equilibrium model, which assumes that other markets do not influence it. The equilibrium price and quantity at which decisions of consumers and producers are consistent with each other is found at the intersection of the supply and demand curves.[3]

A general equilibrium model, shown in Figure 1, is one in which all markets of an economy are represented.[4]

Utility

The economic choices of consumers are assumed to be a rational process of utility maximization, where utility is a function of individual preferences.[5] Utility cannot be precisely quantified and instead is measured ordinally (in relation to other preferences) rather than in absolute terms.[6] The price that a consumer is willing to pay for a commodity is determined by the utility gained from purchasing it rather than other commodities.[7]

In economics, it is assumed that consumers are never satiated. They always prefer greater quantities of a given commodity, and regardless of the level of utility they gain from a commodity they will

GENERAL EQUILIBRIUM MODEL

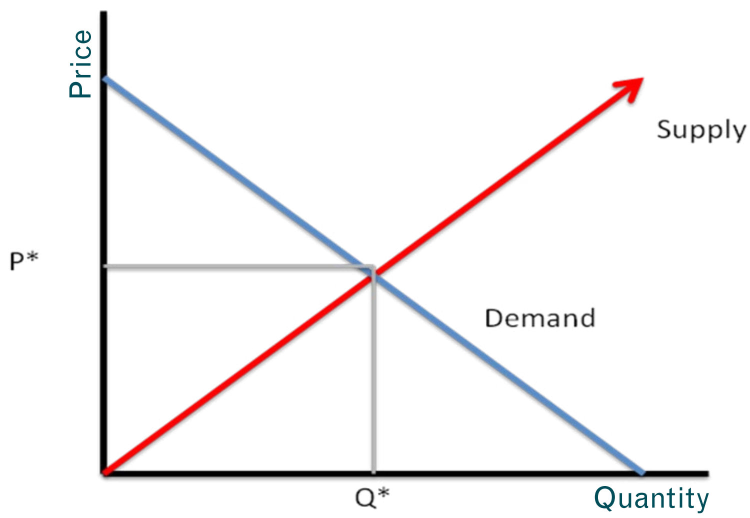


Fig. 1: The General Equilibrium Model shows how supply and demand functions determine the price and quantity of a commodity in the market.

Achieving sustainability will require addressing three areas of human need: Social, Environmental, and Economic.

prefer having some of it having to none of it. However, each additional unit of a commodity is assumed to result in smaller contributions to utility, or, in technical terms, "diminishing marginal utility". Still, the non-satiation assumption posits that a consumer will always prefer to have some amount of a commodity to having none at all.

Opportunity Cost

The economic cost of a commodity is determined by what is given up in order to get it.[8] For example, if a factory is capable of producing either shirts or socks, the cost of producing socks is the foregone opportunity to produce shirts. The opportunity cost of depleting a renewable resource, such as a fishery, is the foregone opportunity to harvest fish in the future. The cost of depleting a non-renewable resource is the missed opportunity of future generations to use those resources. Typically, renewable resources are depleted because of time preference or expectation of future substitutes. Time preference is the choice to have something now rather than in the future, independent of other factors.

Resource depletion also occurs as a result of the expectation that future generations may not need the resource, in anticipation that technological innovation will produce a substitute. For example, nineteenth century whalers were unconcerned with the depletion of the whale stock, despite their reliance on whale oil for light, because they anticipated that other options would become available. This calculation failed to take into account the harm they were doing to the ecosystem or the existence value (value for their own sake rather than as a resource) of the whales.

Macroeconomics

Macroeconomics studies the performance of the economy as a whole. Various indicators, such as employment rates, growth rates, savings and investment, and inflation are used to determine the overall state of the economy. Interaction among various parts of the economy and the effects of policy decisions on the economy is also part of macroeconomics.

Right: "Geothermal Power Plant, São Miguel Island, Azores, Portugal." Photo credit: Jonathan Herz

Public Policy

Macroeconomics also studies the use of policy instruments to affect economic performance.[9] Government spending, interest rates, and the money supply all influence indicators of economic performance.

Growth

Founded in the non-satiation assumption, an increase in economic output (economic growth) is often equated with rising utility levels among consumers. For the macroeconomy, output is measured by Gross National Product (GNP) or Gross Domestic Product (GDP), which capture the market value of all marketable goods and services in a given year by the nationals of a country (GNP) irrespective of their location, or domestically (GDP). A key assumption of neoclassical macroeconomics posits that GDP and GNP are suitable economic indicators of improvements in the conditions for consumers.[10]

For example, in their influential text on economic growth Barro and Sala-i-Martin[11] observe that real per capita GDP in the United States grew by a factor of 8.1 from 1870 to 1990. They then conclude, "Even small differences in… [annual GDP] growth rates, when cumulated over a generation or more, have much greater consequences for standards of living than… short-term business fluctuations…".

Ecological economists dispute the claim that quantitative increase in the *size* of the economy and *qualitative improvement* are linked. Ecological economists posit that the dis-utility generated by the environmental destruction caused by economic growth may be greater than the utility gleaned from that growth. This means that, while the economy may be growing, the quality of life can actually be decreasing, particularly when environmental safeguards are ignored. Macroeconomic theory also assumes unlimited economic growth,[12] whereas ecological economics recognizes that the limits of the natural world constrain the size of the economy.

"Lake Mendota, Madison, Wisconsin." Photo credit: Jonathan Herz

Assumptions and Market Failures

In order for goods to be efficiently allocated in an unregulated market economy, certain conditions must apply. Among these are the conditions are that:

- markets are perfectly competitive
- all decision makers have perfect information
- all households maximize their utility, and
- all firms maximize their profits.

In these circumstances, businesses do not overproduce, waste resources, or create undesirable by-products; and consumers do not over consume and create waste. When these conditions are not met, the unregulated economy fails to create socially optimal conditions and a market failure occurs.[13] Many economists see this as justification for corrective action by government.[14]

Rivalness and Excludability

A good must be rival and excludable in order to achieve socially optimal allocation in an unregulated market. If a good is rival, consumption by one individual reduces availability for all. Rival goods have finite quantities—if person A uses some, it depletes the stock that person B may use. Pizza is rival, as is a bicycle. With a non-rival resource, consumption by one individual does not reduce availability for all. Examples are: light from a street lamp or use of the ozone layer to protect against ultraviolet light (UV).

Excludability is the legal concept that allows an owner to keep others from using his asset. The owner can use it while denying others the right to use it at the same time (e.g., pizza, bicycles, etc.). Non-Excludable goods, also called public goods are those whose use by others cannot be prevented (e.g., climate stability, atmospheric gas regulation, etc).[15]

Public Goods

In an unregulated market, goods that are non-rival and/or non-excludable will not be produced at a socially optimal level because of free-riding: firms have little or no incentive to produce non-excludable goods when they cannot ensure that people will pay to use them, and consumers will have little incentive to buy non-rival goods because to do so would be to accept a personal cost for a public benefit.[16] Therefore, goods that are both non-rival and non-excludable are referred to as public goods because, in order to be produced at a socially optimal level, the public sector must intervene in the market.

Free-Riding

Free-riding occurs when a public good is produced and not all users contribute. Say, for example, a neighborhood wanted to turn an abandoned lot into a public park. People could collect donations from their neighbors to fund the park, but not everyone would contribute. Each individual in the neighborhood has the incentive to not contribute, but enjoy the park. However, if everyone in the neighborhood chose this path of rational self-interest, the park would not be built.

Tragedy of the Commons

It is also worth noting that publicly available goods can be subject to overexploitation. The classic example of this phenomenon is a public pasture on which people graze their cattle[17]. The pasture can sustain a finite number of cattle while still replenishing its grasses. Yet each herder, pursuing personal gain, seeks to maximize the size of his cattle herd. They add cattle until the capacity of the pasture is overwhelmed, resulting in environmental ruin. The tragedy is that the ruined pasture can sustain no cattle because the pursuit of individual gain led to overexploitation.

Externalities

An externality is an unintended consequence of economic activity, which affects individuals other than the decision maker.[18] Externalities can be positive or negative. For example, a positive externality occurs when a building owner plants a green roof: this improves local air quality, provides habitat, reduces the burden on municipal storm water infrastructure, and mitigates the impact on the local waterways. A negative externality occurs when office buildings are sited far from workers' homes, necessitating transportation expenditures by workers and local government and increasing air pollution from cars. Although providing incentives for private actors to internalize the full costs of their actions was long thought to be the theoretical solution to the externality problem, government activity in the environmental realm has been the most effective means of dealing with the greatest externality: pollution.

An externality occurs when one party's actions impose uncompensated benefits or costs on another. Environmental problems are a classic case of externality. Another example is the case of common property resources that may become congested or overused, such as fisheries or the broadcast spectrum. A third example is a "public good," such as defense or basic scientific research, which is distinguished by the fact that it is inefficient, or impossible, to exclude individuals from its benefits.[19]

Addressing externalities that occur across wide geographic distances, or especially across time, is particularly difficult. "When externalities affect future generations, we must accept that transaction costs between generations are infinite, and that the market will not solve the "externality" problem unaided."[20] Distance through time and space makes communication between the party responsible for the externality and the affected party complicated, if not impossible.

Environmental Economics and Resource Economics

Externalities and market failures involving the natural world are addressed by two branches of neoclassical economics: environmental economics and resource economics. These disciplines attempt to respond to problems not adequately addressed by Neoclassical Economics, but they do not depart from its basic worldview. Environmental and resource allocation problems are resolved through these disciplines by attempting to fit these problems within the neoclassical economic model, by methods such as setting prices for environmental goods. By contrast, ecological economics seeks to alter the foundations of our economic models to reconcile them with the realities of the natural world. As prominent ecological economist Joshua Farley said, "Free-market economics works great, for a certain narrow class of goods and services, but there's a huge, broad class of goods and services that are incredibly important to our well-being where it doesn't work at all."[21]

Environmental Economics

Environmental economics is a sub-discipline of neoclassical economics that deals with the allocation of environmental resources. It seeks to correct market failures related to environmental goods, such as ecosystem services, and negatives, such as pollution, to ensure that the economy provides them at a socially optimal level. Topics typical to this field include pricing environmental resources and using policy instruments such as taxation, subsidies and other incentives, and property rights for environmental goods to correct environmental externalities and improve the allocation of environmental resources.[22]

Figure 2 - The Traditional Economic Paradigm

Environmental economics is not a synonym for ecological economics.[23] The key difference between ecological economics and environmental economics is that ecological economics sees the economy as a subset of the ecosystem and is therefore concerned with finding the appropriate economic scale, (figure 2) while environmental economics considers the environment as an aspect of the economy. Environmental economics treats the performance of ecosystems as but one aspect of the function of the economy, whereas ecological economics sees a healthy ecosystem as a necessary precondition of economic activity.[24] The next portion of this review explains ecological economics' position that the human economy exists within the natural world, not as a separate abstract entity to which environmental problems are external.

Natural Resource Economics

Resource economics is a branch of neoclassical economics that studies efficient allocation of natural resources, including the optimal extraction rate of nonrenewable resources.[25] A basic assumption is that a nonrenewable resource can be extracted only once. Therefore, optimal prices of a unit of a resource must reflect not only its cost of extraction but also account for the opportunity costs associated with depleting the resource endowment by that unit.

Traditional economic models employ positive discount rates[26] to reflect the possibility that technological improvement can give rise to increasing economic wealth, and that even though future generations will inherit smaller physical resource endowments, an enlarged stock of human-made resources may compensate for the reduction in the physical resource base. Optimal use of renewable resources is also studied by examining economic factors that influence their depletion and renewal.[27] Sustainable use of resources is studied as it pertains to maximizing utility gained from exploiting these resources, whereas ecological economics is concerned with the benefits bestowed upon humanity from leaving resources intact.

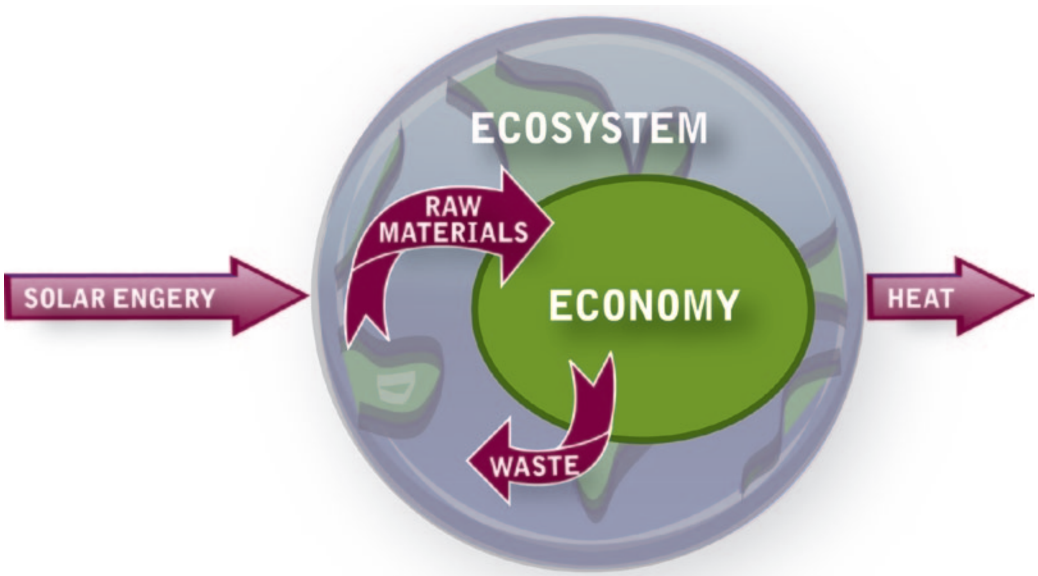


Figure 3 - Ecological economics views the economy as a subset of the larger ecological environment, where low-entropy raw materials flow through the economy and exit as high-entropy waste.

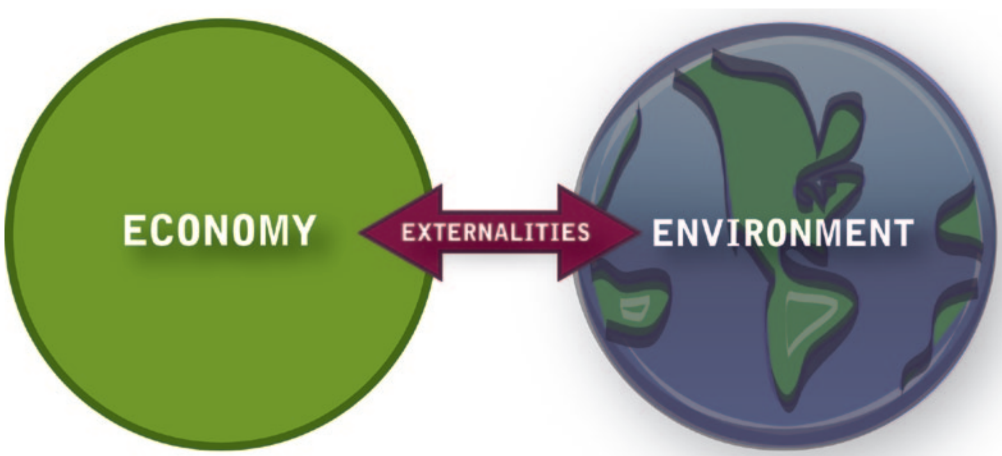


Figure 4 - Neoclassical economics, including environmental economics and resource economics, sees the economy as an abstract entity separate from the natural world. When the economy and environment interact, it is an externality that can be corrected with market-based tools, such as pricing environmental goods.

ecological economics: history and theory

For ecological economists, the economy is a subsystem of a finite, non-growing, materially closed ecosystem. As Figure 3 illustrates, the economy is firmly ensconced within the environment. To neoclassical economists, the ecosystem and the economy are separate entities that, the interaction of which usually creates market failures (See Figure 4). According to ecological economics' model of the world, the economy extracts raw materials from the environment and then sends waste back into it. Economic growth can only occur within the constraints imposed by the finite limits of the natural world. No such limitations apply to an abstracted model of the economy, independent of the physical world, which is employed by neoclassical economics.

As modern economic thought emerged around the 18th century, the idea emerged that economic value is determined by scarcity. In that time human-made capital, such as factories and plows, was relatively scarce, as was labor. Seeming so abundant over this period that it hardly rated a mention in economic theory was 'natural capital' – the natural resources such as fertile soils, supplies of timber, water, minerals and fossil fuels, and the capacity of the earth and its atmosphere to absorb wastes. So, the tools that emerged in the practice of modern economics were based on the assumption that the natural world is infinite, at least in relation to labor and human-made capital.

As a result, human technical ingenuity has focused on better and better machines, and has improved the productivity of labor using those machines on an extraordinary scale. The work of two hundred workers in 1770 could be done by a single spinner in 1812.[28] One can scarcely guess by what order of magnitude modern technology has improved labor productivity since 1812. In addition, the human population has grown astronomically during that time. We now live in a full world, in which natural capital is scarce in relation to human beings and man-made capital. For example, the productivity of our fisheries is no longer determined by the amount of fishermen and boats, but by the amount of fish in the water. Today, mainstream economic theory continues to focus on the allocation of labor and capital, to the exclusion of the natural world.

Ecological economics addresses the failures of the neoclassical economic paradigm by treating goods and services from the natural world are vital components of the human economy. Ecosystem processes provide energy and regulate wastes, and natural resources are used for a variety of goods and services including food, medicine and recreation.[29] Ecological economics is an interdisciplinary field that studies the allocation of these natural resources, with emphasis on the view of the human economy as a subset of the ecological world. Drawing upon expertise from the natural and social sciences, ecological economists seek to include natural resources in the traditional economic view as a capital stock, of sorts, that can be used by the economy.

A central tenet of ecological economics lies in the recognition of biophysical limitations on economic growth and instead favors sustainable development. The field builds on traditional ideas of sustainability to include responsible use of resources that does not preclude future generations from enjoying standards of living comparable to those of citizens today. The literature review documents the work that defined ecological economics as a discipline, and highlights the key tenets of the field as a philosophical and theoretical foundation from which to build an understanding of how to include concepts of sustainability in business and policy making.

Economy as a subset of the environment

Traditional economics views our economy as separate from the surrounding environment with potential for infinite expansion. From an ecological standpoint, the economy is actually a subset of the larger natural world, limited in its expansion by the laws of thermodynamics (Fig 3). The first law of thermodynamics states that matter and energy can neither be created nor destroyed, so the economy must use resources provided by the natural world. The second law of thermodynamics states that all things tend towards entropy; they become less useful. Economic production begins with low-entropy materials, such as natural resources, and ends with high-entropy wastes. Ecological economics is concerned with the rate at which the economy uses natural resources and ecosystem services. As resources flow through the economy (a process known as throughput) natural goods are transformed and ultimately released as wastes.

Ecosystem services are natural functions that have value to humans. These services include natural processes like oysters filtering the toxins out of water in a bay, or trees sequestering carbon dioxide from the air. The environment also provides capital in the form of food and raw materials for human-made goods. Ecologists, who study ecosystems, cannot identify every aspect of the systems or their functioning. It is impossible to measure the precise value of these services, although various accounting measures have been developed to provide approximate monetary values. The ecological footprint and life cycle assessment (LCA), for example, has been applied to assign value to the environment based on the revenue generated by associated economic markets.[30]

Because the world is a closed system, there is a finite base of natural resources with which to create goods, and this base is depleted by economic growth. Many of these resources are nonrenewable and even renewable resources are frequently consumed more quickly than they can be replaced. Technological innovation can facilitate more efficient resource use, but technology itself – however rapidly changing – cannot function without a minimum of materials and energy.

As economic growth continues to occur, the environment shifts from an 'empty world' (i.e. many natural resources available) to a 'full world' (i.e. most natural resources have been appropriated and even depleted by the economy).[31] During this transition, there is a point of economic growth beyond which human welfare is in fact reduced rather than increased.[32]

Improving Welfare: Growth vs. Development

Gross Domestic Product (GDP) and Gross National Product (GNP) are standard measures of economic growth. Growth is often linked to increasing welfare despite the fact that unfettered growth may actually reduce welfare in the long run. Empirical evidence exists[33], for example, that ever larger portions of GDP are diverted to address undesirable consequences of growth, thus raising GDP even further. In contrast, development refers to qualitative improvement in quality of life. Developing economically focuses on the ability to make improvements in the designs of existing commodities and institutions that improve the scale, allocation, and distribution of resources.

> *"Gross National Product, as well as other related measures of national economic performance have come to be extremely important as policy objectives, political issues and benchmarks of the general welfare. Yet GNP as presently defined ignores the contribution of nature to production, often leading to peculiar results."* [34]

Ecological Economics and Public Policy

Economic policy should be directed towards achieving three policy goals: optimal scale, efficient allocation, and just distribution. This document focuses on scale, as it is the policy area most relevant to the General Services Administration's sustainability initiatives. Also, many ecological economists would argue that conventional economic thought already addresses efficient allocation and it is necessary for scale to be addressed before distribution can be addressed in a meaningful way. Together, these three policy areas represent a three-pronged model of sustainability in which environment, society, and economy are interdependent.

Optimal scale

In economic terms, scale refers to the volume of matter and energy used to provide goods and services in the economy. Many ecological economists posit that our current scale of natural resource use is unsustainable, and that the human economy is approaching the full world scenario in which growth is uneconomic.[35] This is in part due to negative externalities (e.g. pollution) resulting from growth and from failure of the market to capture scarcity of resources without monetary value.

Command-and-control regulations have historically been the primary mechanisms for setting limits on resource consumption. These policies set strict limits on pollution, extraction or harvest levels and fine firms for violation. However, there has been a recent shift in the discourse about the effectiveness of such policies in favor of more flexible solutions that provide incentives to reduce scale beyond one set cap in a more cost-effective manner (e.g. Pigouvian taxes, tradeable permits). Economists from all disciplines continue to debate the merits of market-based environmental policies versus the traditional command-and-control approach.

Efficient allocation

While accepting of the basic laws of supply and demand as useful tools of market analysis, ecological economics draws attention to the insufficiency of the market to allocate many types of natural resources. Open-access regimes such as fisheries, for example, are nonexcludable (i.e. traditionally lack property rights) and individuals may overexploit these resources because any costs incurred are shared among many other individuals also using the resource. Public goods (e.g. fresh water, clean air, scenic beauty) are subject to similar effects because they can be used for free and thus scarcity will not be adequately reflected in the market price.

Environmental economics suggests that some of these problems can be solved by assigning prices to natural resources and taxing polluters. Public policy mechanisms can make effective use of price estimates for ecosystem services. In Costa Rica, landowners are paid to preserve their land based on estimated values of biodiversity, carbon sequestration and scenic beauty.[36]

Ecological economics, while generally not averse to this solution, sees clear limitations and emphasizes the intrinsic and moral value of ecosystems and their role in supporting the human endeavor that is fundamentally different from the contributions that come from ordinary goods and services.[37] Policy mechanisms and business practices can be developed to reflect the fact that natural goods and services do have some value without attempting to calculate a dollar value for each. The Endangered Species Act is a classic piece of legislation in the United States that reflects this ideal through policy. Wildlife classified as threatened or endangered is given implicit value in its protection by the law, without attempt to monetize the value of a given species or biodiversity as a whole.

Business and industrial practices can also be developed to reflect the fact that natural goods and services do have value without attempting to assign specific dollar values. For example, production methods that minimize waste generation can limit throughput and environmental impact. Efficiency in production is highest when complemented by attention to input volume, since costs associated with the rate of resource consumption can outweigh the benefits from reduced waste generation.[38]

Just distribution

Ecological economics places importance on the distribution of wealth and income for sustainability and responsible use of resources. Income distribution can undermine sustainability because poor communities may not be able to afford dealing with environmental impacts, while the very rich consume vast amounts of limited resources and may be better able to adapt to growing resource constraints or decreasing environmental quality. Policies designed to remedy this situation include progressive income and wealth taxes, mandated minimum wages, unemployment insurance and welfare programs.

Defining sustainability

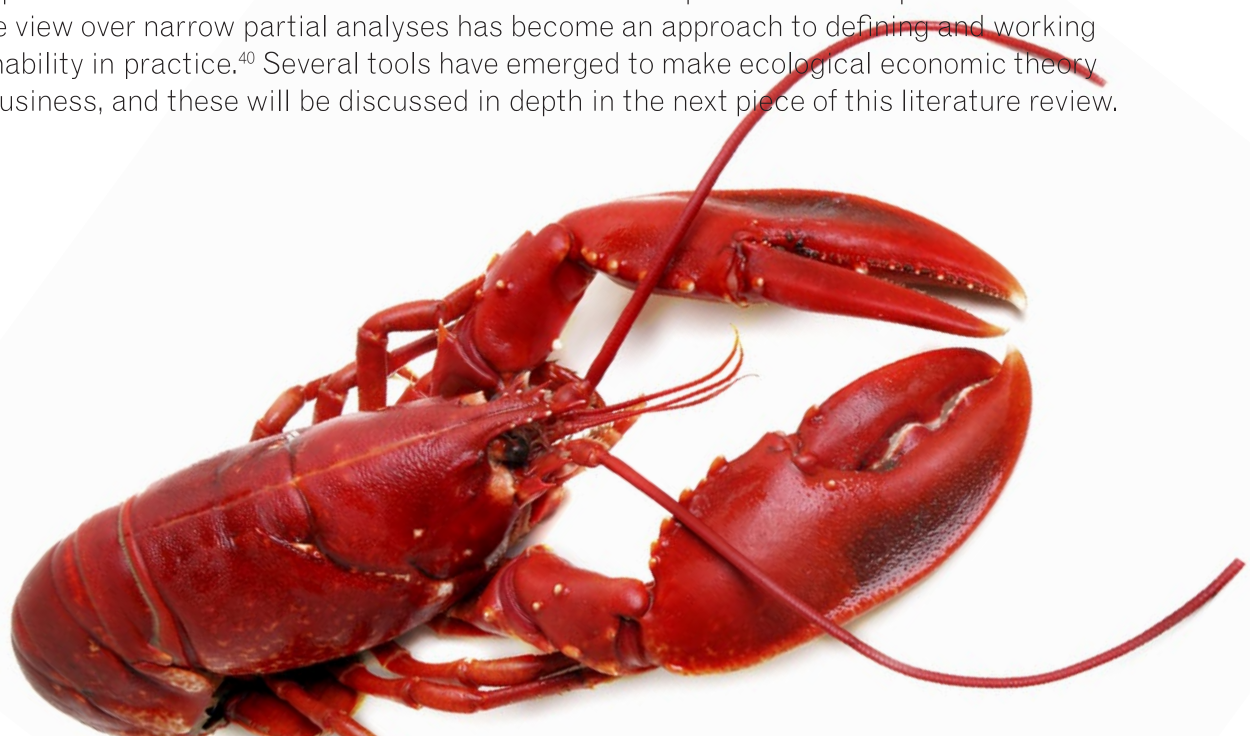
Ecological economics charges the present generation to carefully examine the relationship between the economy and the ecosystem that encompasses it. The scale of the economy should be constrained to the point where the present generation does not compromise future generations' ability to use natural resources and services. Defining sustainability in a precise way is tricky as it involves normative judgments about the present generation's obligations to future generations and assumptions regarding technological progress.[39] A sustainable economy requires a long-term view of income. Ecological economics defines income as the amount that can be consumed without depleting the ability to consume the same amount in the future.

Consumption of capital (including natural capital) does not count as income because it makes the community (or the ecosystem) less able to produce goods in the future. So, depleting a fishery at a greater rate than it can replenish itself does not create income, it is consumption of natural capital that depletes future wealth. Spending capital, including natural capital, can create short-term economic growth, but should not be confused with income. The distinction is that income is a return on capital whereas capital depletion destroys the ability to earn income.

Increasingly, the discussion of sustainability has evolved into analyses involving multiple stakeholders from the sciences and from business that focus on systems-level management strategies and holistic approaches to production. A holistic viewpoint of complex interactions maintains that a single part within a network can be best understood not in isolation, but rather in the context of its relationship to other parts and its function within the larger whole.

The field of industrial ecology studies the intricate relationship between the environment, economy, and technology that exists within industrial systems. An industrial system is a network of production and consumption built of several steps of varying complexity from raw materials to marketable products to their use and return to the environment or other parts of the economy. This network exists within, and is dependent upon, the larger ecosystem that provides a stock of natural capital for the creation of products and assimilation of wastes. The ways in which industrial processes are designed and end products are used determine the degree of impact on the environment, and in turn the condition of resources available for production. The socioeconomic environment also factors into decision-making regarding scale of resource use, design of products and industry structure, as well as impact on the biophysical environment.

As with other complex networks, a perturbation in any part of the broad industrial-ecological system can cause adjustments in other parts of the network. Because unintended consequences become ever more likely as the size of the operation (a production process or the economy) increases, implementation of solutions to problems must be done with care to avoid adverse repercussions. Emphasis of a comprehensive view over narrow partial analyses has become an approach to defining and working toward sustainability in practice.[40] Several tools have emerged to make ecological economic theory applicable in business, and these will be discussed in depth in the next piece of this literature review.



translating theory into practice: tools and applications

A major challenge to achieving sustainable development as is the practical application of theory. This section reviews some of the major tools for incorporating the theories of ecological economics into policy, business and industrial practices including extension of traditional decision-making and cost-benefit analysis, life cycle analysis and industrial ecology. The section also presents general criteria indicators for inclusion of sustainability into the micro and macroeconomic views of welfare, and backcasting theory as a method to integrate sustainable development in microeconomic business strategy.

Decision-making toward sustainability

Cost-benefit analysis (CBA) is a common tool used to choose between potential projects or courses of action. The costs and benefits of the impacts of a proposed activity are evaluated with the goal to determine all of the parties affected by the activity, and to place a monetary value of the effect an activity has on economic welfare. Choices are made by seeking out activities with the lowest cost-benefit ratio. Ecological economists take issue with the traditional practice of CBA as a decision-making tool because it does not account for potential costs/benefits of actions that do not have monetary values and because it limits the criteria for decision making, often avoiding valuable perspectives and interests of broader stakeholder groups. Empirical analyses comparing the realized costs and benefits of projects to previously estimated values have revealed frequent inaccuracies.[41] For example, it is impossible to accurately price natural resources, ecosystem services, social institutions, and human lives.

Multi-criteria analysis (MCA) is a technique that facilitates the use of both qualitative and quantitative measurement scales, which makes it possible to address multidisciplinary problems involving consequences on the environment and/or public health issues.[42] This process includes the participation of many interested parties in decision making and in problem solving, and is focused on compromise or defining a coalition of views rather than dictation of judgment from a single stakeholder category. Its potential stands is greatest in situations involving multiple value systems and objectives, which cannot be easily quantified (e.g. environmental issues) or translated in monetary terms due to their intangible nature (e.g. social, cultural or psychological issues).[43]

An MCA usually begins by identifying all the potential impacts of each decision, and a set of criteria that all stakeholders find important for choosing among alternatives. The potential options are then ranked using methods that range from simple hierarchical systems to more complex algorithms.[44] The ranking of alternatives is then used as a template to guide the final decision and to understand the implications of choosing one option over another, rather than identifying a single 'best' option.[45]

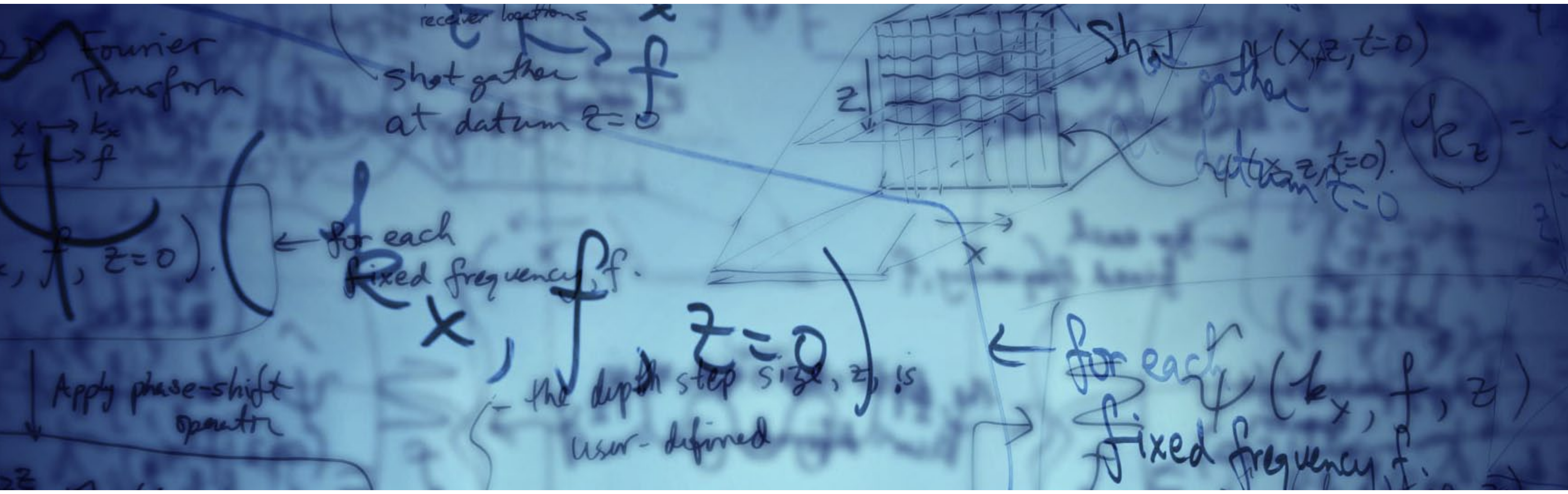
Multidisciplinary stakeholder involvement is an important aspect of understanding alternatives to a problem and identifying the most desirable solutions. To gain a comprehensive picture of the social, economic, and environmental impacts of a decision requires input from individuals with a wide range of views and knowledge, including decision-makers, scientists and engineers, and the general public. Reliance solely on expert opinion, or on the perspective of a single stakeholder, when conducting MCA provides solutions that may satisfy only narrow interests or may have undesirable consequences for another group.[46]

Sustainability in industry

There has been increasing attention to the greening of industrial practices as a component of sustainable development. Industrial ecology is the study of the interaction between industrial and environmental systems, emphasizing design of manufacturing processes that minimizes waste and reduces environmental impacts. Uniquely viewing human industry as part of a dynamic, linked network that includes the environment and the economy, industrial ecology seeks approaches to sustainable use of resources that work well from a holistic perspective.

Experts from a range of backgrounds including the natural and physical sciences, public policy and law have joined a discourse that has expanded from questions regarding efficiency of material and energetic flows in industrial processes to include concerns about biodiversity, sustainable development and public health. Specifically, research topics include determination of material inputs to production, improvements of environmental impacts through technological change, institutional and managerial responsibility for product design, development of eco-efficient industries and industrial parks, and policy incentives for environmentally friendly practices.

Increasingly, firms implementing responsible production techniques have broadened their approaches to material use from a “cradle to grave” to a “cradle to cradle” perspective, continually reusing and recycling waste rather than creating products that are ultimately discarded wholesale.[47] This perspective takes into account not just relations among processes but also the broader infrastructures and social systems that constrain these processes and influence their development. InterfaceFLOR’s carpeting systems, for example, are designed so that only worn tiles of carpet are replaced over time, rather than discarding an entire flooring system when only few areas are damaged. Old tiles are recycled and used as inputs to new production cycles, along with other renewable materials. This production cycle limits the extraction of raw materials needed to provide the flooring service, and minimizes net waste products.



Life cycle assessments

Part of the challenge of transitioning from a linear, through-put oriented system (in which raw materials are input and wastes are output) to a closed-loop production system (in which materials are recycled and wastes are eliminated) is accounting for energy balances and resource flow from a product, starting with a raw material and ending at the point at which the product is no longer usable. Life Cycle Assessments are production budgeting tools used to inventory all transfers of energy and materials to the environment, to characterize impacts of each release, and to identify areas for efficiency improvements to reduce impacts. One such area is the design of products for maximum reuse of its constituent parts. A systems perspective is particularly important in these analyses to ensure that potential improvements aren't canceled out by costs in another part of the network.

Because they tend to be focused on single products or processes, Life Cycle Assessments are often interpreted in tandem with impact assessments of different foci. Environmental Impact Assessments, for example, evaluate and model waste emissions from entire plants or firms. Cost evaluation techniques (e.g. cost-benefit analysis) can then be used to compare potential methods to reduce impacts. Combining impact assessments from the perspectives of technical, ecological and socio-economic systems provides a comprehensive, higher-order picture of the industrial network for experts to use when considering efficiency improvements.

Life Cycle Cost Analyses are similar tools that can be used to choose among production options by examining costs and benefits over the entire life cycle of a product. The truly cost-effective option is not necessarily that with the lowest procurement costs, but the lowest cost:benefit ratio over a product's economic life. These analyses may include not only material inputs, but also more complex facets of a product. In building design, for example, one may want to consider operating and maintenance costs, productivity of workers in the environment, and savings values from efficiency measures (e.g. windows to make use of daylight versus more electric lighting).[48]

Technological innovation

Technological innovation often plays a key role in moving from open to closed loop systems by increasing efficiency of industrial processes or aiding in the recycling of waste products. In any given

industry, manufacturing equipment has different efficiency and production capacity over its lifetime. For example, a machine that produces aluminum cans might have a typical lifespan of 35 years, over which time it becomes less efficient at using energy to manufacture the cans in the absence of investment and improvements. This production capacity of manufacturing equipment over lifetime, known as capital vintage structure, to a certain extent 'locks in' production methods and efficiency because upgrades and improvements to industrial capital can be very time-consuming and expensive.

There is a burgeoning area of study within industrial ecology dedicated to the economics of such innovation, emphasizing the timing of change and improvements based on the technological inertia in the industry. Systems modeling is typically used to set potential schedules representing the most cost- and energy-efficient time scales for implementing innovative technological change. For example, the energy-intensive pulp and paper industry is a recent target for CO2 emissions reductions. Researchers in Europe and the United States have used dynamic modeling to investigate the impacts of various policy options on emissions given the capital vintage structure (i.e. the lifetime capacity and age structure) of pulp and paper plants.

Industrial ecology emphasizes the design of new products that anticipates environmental impacts from the start, ideally saving manufacturers costs of cleanup or improvements in the future. The "design for environment" (DFE) approach joins the capital vintage approaches described above with comprehensive environmental assessments toward a forward-thinking view of design. Typically product-oriented, this approach focuses on reduction of toxic material use, potential for recycling and manufacturer responsibility as a feature of product development rather than an afterthought. The movement toward green cars (e.g. hybrid and electric vehicles) from 'end-of-pipe' mechanisms to reduce emissions (e.g. catalytic converters) represents an ongoing application of DFE. Installation of green roofs and vegetation in cities can reduce air temperatures, leading to less energy use for air conditioning and water use for cooling in industrial buildings.

"South San Francisco Bay, California." Photo Credit: Jonathan Herz

Networking sustainability

One archetypical example of sustainable production in practice is an integrated industrial network in Kalundborg, Denmark. Borrowing the adaptive strategy of mutualism (co-beneficial relationships) from nature, this and other eco-industrial parks share materials and energy among participating firms in an effort to achieve greater returns to production than can be achieved when each firm operates independently. These cost savings are incentives for firms to participate in business practices that often result in efficiency improvements and reduced waste emission. Six firms including an oil refinery, a plasterboard firm and a pharmaceutical company trade waste for reuse and recycling, recover solvents for manufacturing processes, and share transportation and security services. Over the past 30 years since the park was founded, evolution of the symbiosis has amounted to substantial annual energy savings; for example, resource exchange between the refinery Statoil and the power station Asnes saves the firms 1.2 million cubic meters of water and 30,000 tons of fossil fuel per year, respectively.[49]

Businesses around the world are beginning to apply industrial ecological approaches from the eco-industrial park model to smaller-scale partnerships. Texas Industries, for example, enjoyed an increase in cement production and decrease in energy consumption following a 1999 agreement to re-use waste products from neighboring Chaparral Steel. Similar symbiotic developments have emerged throughout the United States and abroad in Japan, Canada and Puerto Rico, among others.

Backcasting

Backcasting is a methodology that aims to provide decision-makers in organizations with an idea about the underlying systemic dimensions of the challenges they deal with. Backcasting can best be defined in contrast to forecasting. Forecasting, as a strategy tool in business and policy, is based on observation of past trends, which are then extrapolated to describe the most likely future developments. The problem inherent in a forecasting approach is a strategic lock-in to undesirable developments, such as ever-growing energy demand. This approach can be called “path-dependent.”

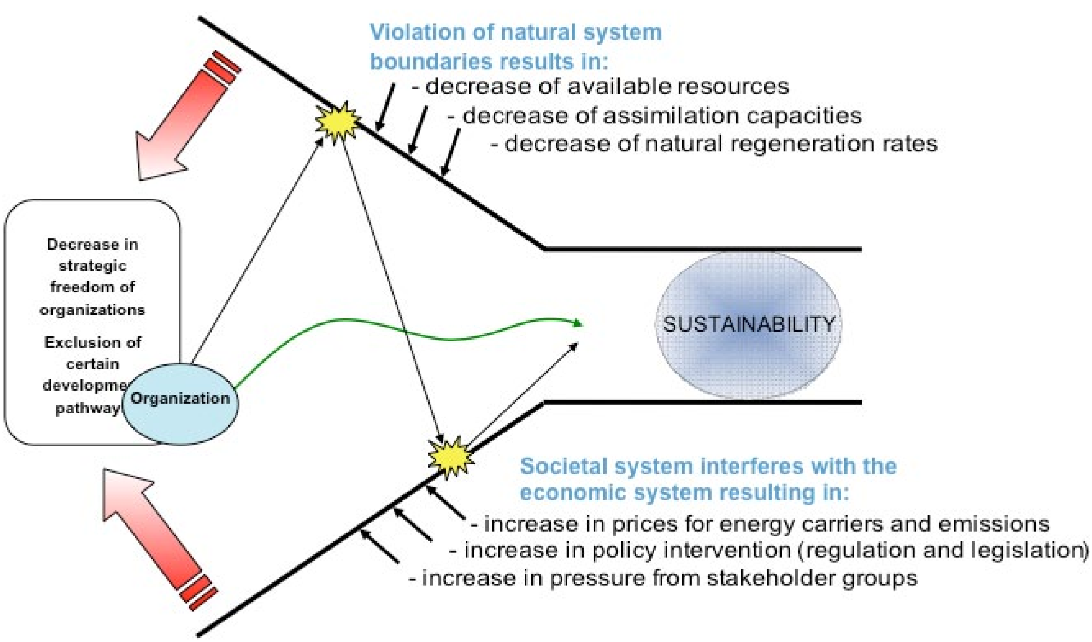


Figure 5: Figure based on Holmberg 1998, p. 35 and Nattras & Altomare 2006, p. 20.

Extrapolation of past developments and practices as a basis for realizing a more sustainable future does not usually take into consideration overall system limitations (i.e. acknowledge the problem of scale). Backcasting, as an alternative method in future studies, approaches the issue of path-dependency and desirability of long-term outcomes from the opposite perspective. First of all, a desirable long-term sustainability target is defined. After the target is clarified, a backcasting methodology is used to analyze the status quo in a detached manner that opens the horizon of decision makers for problem solving (See Figure 5). The actual backcasting process is a comparison of the pre-set target and the status quo, such as establishing a goal of 350 parts per million carbon dioxide in the atmosphere to diminish the effects of global warming.

This comparison highlights necessary steps that link the present to a desirable future. In an organizational environment, backcasting will ideally yield tangible milestones all along a time line towards the long-term target and thus help to operationalize sustainable development. Decisions under strategic backcasting are therefore always evaluated against the target scenario, they are ranked according to their capability to realize sustainable development rather than short-term profitability. Backcasting consequently requires long time spans to unfold its methodological advantages; time spans of 20 to 100 years are manageable with the method that was developed for policy scenarios but is now increasingly applied in organizations (corporations, municipalities, agencies etc.) to ensure a desirable strategic development within a long time horizon.

Discounting

Discounting is the process of systematically devaluing future costs and benefits. This is done in order to compare present costs and benefits with those occurring in the future, by calculating a net present value. There are a number of reasons for discounting the future: uncertainty about future technological or economic conditions, expectations of economic growth or future productivity, or pure time preference for the present. The discount rate is the rate at which future assets are devalued in present accounting. So, choosing an appropriate discount rate is crucial if we are to reserve and appropriate amount of resources for future use. The Office of Management and Budget uses a discount rate of seven percent in most calculations to reflect expected returns on private sector investment.[50] At that rate, an investment that yields $100 50 years from now but requires an investment of 4 cents today will not be carried out. As a result of high discounting, many projects that could address climate change, for example, are not carried out, because investments today may be large and benefits may not be seen until a distant future.[51]

Ecological economics approaches discounting differently. When future returns are discounted due to an assumption of increased productivity or economic growth, it must be realized that this implies an increase in the size of the economy relative to the ecosystem and therefore environmental destruction. Discounting is problematic when it assumes future economic growth because growth cannot be sustained indefinitely.[52]

The appropriate use of discounting is crucial to improving the sustainability of the federal government's operations. Many sustainability initiatives necessitate start-up expenditures with expected future benefits. Retrofitting buildings to make them more energy efficient, for example, requires spending money in the present to attain future financial and ecological benefits in the form of energy savings. Because discounting devalues future financial benefits, an inappropriately high discount rate may discourage decision-makers from undertaking these retrofits. Discounting devalues the future, which precludes policymakers from engaging in the kind of long-term planning necessary for sustainability.[53]

Indicators

One of the prevailing themes of ecological economics has been the critique of existing measures of welfare, especially the GDP and related indicators. While these were never intended to represent the well-being of a society,[54] they are being used that way both by economists and policymakers.[5]

The GDP does, however, include many activities that actually reduce welfare, such as the destruction of the environment. It further counts expenditures that are defensive, compensating for the effects of

growth without giving additional benefits themselves. Costs of commuting or for the protection against UV radiation are just some of the examples. On the other side, the GDP fails to integrate activities that clearly do contribute to well-being, especially household labor, and only partially counts public activities like education. As an additional shortcoming, GDP does not take social inequality into account, even though it clearly affects welfare. Finally, standard national accounting does not consider sustainability, it does not assess if current growth is occurring at the cost of future generations.[56]

To compensate for the inadequacy of GDP as an indicator for the progress of a society, various alternatives have been designed. These range from happiness indicators relying on survey data[57] through aggregate social indicators like the UN Human Development Index to indicators that make certain corrections to standard national accounting. The Index of Sustainable Economic Welfare (ISEW)[58] and the Genuine Progress Indicator (GPI)[59] have been applied in many settings, using personal consumption as a basis, but making corrections for environmental degradation, inequality, defensive expenditures, household labor and more, with dozens of corrective steps.

While some weaknesses to these alternative indicators have been shown,[60] such as a tendency to continue to monetize elements, they clearly provide a better approximation of progress than GDP can. Almost all calculations for industrialized countries have shown that sustainable economic welfare has already peaked, and further economic growth might well lead to a lower level of welfare.[61] This can be explained by economies surpassing their optimal scale, eliminating growth in GDP as a valid policy goal; growth in welfare must be achieved.

"Downtown Atlanta, Georgia." Courtesy of NASA/Goddard Space Flight Center Scientific Visualization Studio

Endnotes

1. Pareto, 1906.
2. Ricardo, 1971, and Samuelson, 1983, ch.9
3. Arow and Debreau, 1954
4. Malinvaud, 1972
5. Samuelson, 1983, ch.5; for alternative assumptions on consumer behavior see, e.g. Julian Simon's work on bounded rationality (1982).
6. Arrow, 1970
7. Friedman and Savage, 1948
8. Samuelson, 1983, ch.4
9. Baumol, 1967, ch.15
10. Baumol, 1967, ch.9
11. Barro and Sali-i-Martin, 1995, p.1,4
12. Romer, 2005
13. Bator, 1958
14. Samuelson, 1983, ch.8
15. Daly and Farley, 2004, p.73
16. Samuelson, 1954
17. Hardin, 1968
18. Stavins, 2004
19. U.S. Office of Management and Budget, 1996
20. Daly and Farley, 2004, p. 179
21. Harris, 2003.
22. Cropper and Oates, 1992.
23. Costanza, Daly, and Bartholomew, 1991.
24. Daly and Farley, 2004.
25. Conrad and Clark, 1989
26. Concept of discount rates is elaborated on in Section III.
27. Sollow, 1974
28. Hawken et. al., 1999, p.7.
29. Daly and Townsend, 1993.
30. Wackernagel et. al., 1999
31. Farber et. al., 2002
32. Max-Neef, 1995
33. Talbarth et. al., 2006
34. Costanza, Daly, and Bartholomew, 1991, p.11
35. Daly, 2005
36. R. Castro, F. Tattenbach, L. Gámez, N. Olson, The Costa Rican Experience with Market Instruments to Mitigate Climate Change and Conserve Biodiversity (Fundecor and MINAE, San José, Costa Rica, 1998).
37. Sagoff, 2004
38. Waggoner and Ausubel, 2002
39. Ruth, 2006
40. Garner, 1995
41. Bent et. al., 2002
42. Romero and Rehman, 1987
43. Stahl et. al., 2002, Wittmer et. al., 2006
44. Zopounidis and Doumpos, 2002
45. Kiker et. al., 2005
46. Kiker et al. 2005
47. Braungart et al., 2007.
48. Cost-Effective, Whole Building Design Guide, 2007
49. Lambert and Boons, 2002
50. U.S. Office of Management and Budget, 1992.
51. Azar and Sterner, 1996.
52. Martinez-Alier and Schlupmann, 1999.
53. Zerbe, 2007.
54. Juster, 197.3
55. Barro and Sala-i-Martin, 1995.
56. Daly, 1996
57. Veenhoven, 1995
58. Cobb and Cobb, 1994
59. Talberth, Cobb, and Slattery, 2007
60. Neumayer, 1999
61. Stockhammer et. al., 1997

economic literature review

GSA and The New Sustainable Frontier

gsa and the new sustainable frontier

This literature review is intended to aid the understanding of the principles of sustainable development by presenting a background of economic theory in general to provide context for the principles of ecological economics, history of the seminal works and principal themes of ecological economics as a discipline, and providing examples of applications of these themes in business and industrial enterprises. The review includes an overview of mainstream economic theory to familiarize readers with the terminology of economics and provide context for ecological economics, a synthesis of the principles of ecological economics, and a description of tools used in the practice of ecological economics.

The following brief overviews of pertinent literature served as preparation for the GSA and the New Sustainable Frontier workshop that took place on March 6th, 2009. For more in-depth reading, please use the links to find the literature in its entirety.

1. A New Approach to Environmental Decision Analysis: Multi-Criteria Integrated Resource Assessment (MIRA)
2. Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection.
3. Ecological Economics: The Concept of Scale and its relation to allocation, Distribution, and Uneconomic Growth.

A New Approach to Environmental Analysis: Multi-Criteria Integrated Resource Assessment (MIRA)

Authors: Cynthia H. Stahl, US EPA Region III and University of Delaware; Alan J. Cimorelli and Alice H. Chow, US EPA Region III.

http://ceep.udel.edu/publications/sustainabledevelopment/publications/2002_sd_new_approach_mira.pdf

The authors present Multi-Criteria Integrated Resource Assessment (MIRA) as a new approach to environmental analysis. MIRA allows for stakeholders to analyze separate identities of data and social judgments to arrive at a conclusion made on mutual stakeholder intelligence. MIRA's key features include: indexing, criteria weighting, learning, and the increased opportunity for consensus building.

The authors identify occurring conflict within a neoclassical system; complex social, economic, and political issues cannot be resolved by the typical singular route it employs. They argue that policymakers need a multi-criteria decision analysis framework in order to adhere to the social and ecological factors affecting the given situation. Through the MIRA process, single optimal answers are avoided. MIRA offers policymakers the choice of rethinking options at each stage in the analysis process towards an end goal of obtaining sustainable environmental policy.

9 Steps of the MIRA Process

1. Define the decision question; decide on decision criteria based on that question
2. Select the 'problem set' which is the set of elements (the decision options or pollutant sources) that are to be ranked using MIRA
3. Gather the data needed for each criterion
4. Index the set of elements
5. Weigh the criteria
6. Create an initial 'decision set' (a problem set whose elements are ranked based on the data and criteria weighting)
7. Create different decision sets for the initial problem set and modifying that problem set if Appropriate as learning occurs and additional options are discovered;
8. Discuss these with stakeholders
9. Make the final decision

MIRA Methodology

1. Determine criteria (stakeholder participation) and define with a metric (data input)
2. Index criteria (expert)
3. Initialize with values (preference schemes)
4. Obtain ranked list of options Iterate

Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection.

Authors: Lisa Heinzerling and Frank Ackerman. Georgetown Environmental Law and Policy Institute, Georgetown University Law Center.

Date: 2002

http://www.ase.tufts.edu/gdae/publications/C-B%20pamphlet%20final.pdf.

In recent years the use of "cost-benefit" analysis to inform environmental standards and policy has attracted a large and high-profile group of supporters. Cost-benefit analysis tries to mimic a basic function of capital markets by setting an economic standard for measuring the success of government's projects and programs. Cost-benefit analysis adds up the benefits of a public policy and compares them to the cost.

There are 2 typical arguments in favor of cost-benefit analysis. First is that cost-benefit analysis furthers efficiency by ensuring that regulations are only adopted when benefits exceed costs and by helping direct attention to those problems for which regulatory intervention will yield the greatest net benefits.

Second, CBA is believed to produce great transparency and great objectivity, thus being more accountable to the public.

Pricing the Priceless argues that cost-benefit analysis is a deeply flawed method that repeatedly leads to biased and misleading results. In comparison to other economic approaches Cost-Benefit Analysis offers no clear advantages in making regulatory policy decisions and often produces inferior results, in terms of both environmental protection and overall social welfare.

The primary flaw is that cost-benefit analysis seeks to monetizing benefits such as the value of life and a healthy environment, for which there are no natural prices. Cost-benefit analysis therefore requires the creation of artificial ones. This process of reducing life, health, and the natural world to monetary values is inherently flawed.

Another flaw is that cost-benefit analysis uses discounting to systematically and improperly downgrade the importance of environmental regulation. While discounting makes sense in comparing financial investments; it should not be applied when choosing noneconomic harms to present generations and preventing similar harms to future generations. Additionally discounting tends to trivialize long-term environmental risks, minimizing the very real threat our society faces from potential catastrophes and irreversible environmental harms, such as those posed by global warming.

Additionally, cost-benefit analysis ignores the question of who suffers as a result of environmental problems and therefore, threatens to reinforce existing patterns of economic and social inequality. Cost benefit analysis would justify imposing greater environmental burdens on them than on their wealthier counterparts.

Finally cost-benefit analysis lacks transparency because it rests on a series of assumptions and value judgments that cannot remotely be described as objective. These make it extremely difficult for the public to understand and participate in the process.

The article does fail to offer a conclusive recommendation on what alternatives are out there. A comprehensive compare and contrast against the listed methodologies would be useful.

Ecological Economics: The Concept of Scale and its relation to allocation, Distribution, and Uneconomic Growth

Authors: Herman E. Daly. School of Public Affairs.
University of Maryland

Date: October 2003.

http://www.publicpolicy.umd.edu/faculty/daly/Scale%20paper%20rev%20final%20copy.pdf.

Ecological Economics is an interdisciplinary field, with conceptual roots in thermodynamics, ecology, and economics. Ecological Economics seeks to understand how human behavior is constrained by, and integrated with, the natural world and its physical laws.

In reviewing these concepts, Daly breaks this overview into 5 parts. First, he looks at Ecological Economics from the outside- summarizing views of scholars from various disciplines interested in ecological economics, their comparisons to neoclassical. Second, he looks at the main features and issues of ecological economics. Third, he looks at the meaning of economic growth in the scale of the physical economy. Fourth, he offers policy implications related to ecological economics and fifth, the author considers alternative formulations on why optimal allocation presupposes a given scale.

Selected quotes from scholars on Ecological Economics:

a. "[Ecological Economics] is problem focused rather than concerned with abstract modeling, and in contrast to conventional neoclassicism, ecological economics shifts the focus from micro to macro and relevant time frames from the very short term to deep time…"

b. "What the ecological economists have to say about the inherent flaws of neoclassical economic theory from an ecological perspective is, as we shall see, quite devastating, and many of their proposed economic solutions to environmental problems are carefully reasoned, beautifully conceived, and utterly appropriate. But if this is the case, why is there virtually no dialogue between the ecological economists and the mainstream economists who sit at the right hand of global planners?"

Daly summarizes ecological economics as having three priorities: allocation of resources, distribution of income, and scale of the economy relative to the ecosystem.

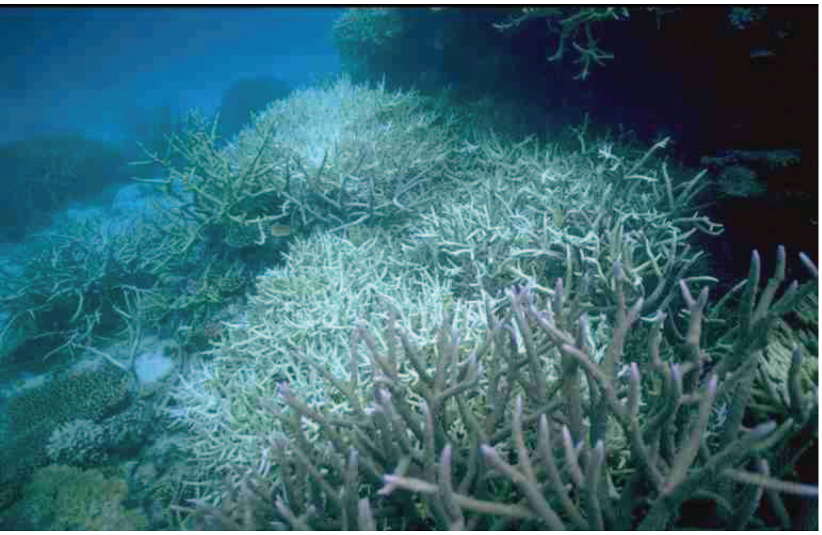
A good allocation of resources is efficient; a good distribution of wealth is just. The defining difference between ecological and neoclassical economists is the emphasis upon distributive "fairness." For ecological economists, fairness is much more pressing. They view the economy as a growth that encroaches upon the existing, finite ecosystem. Therefore, scale determines what is scarce and what is free.

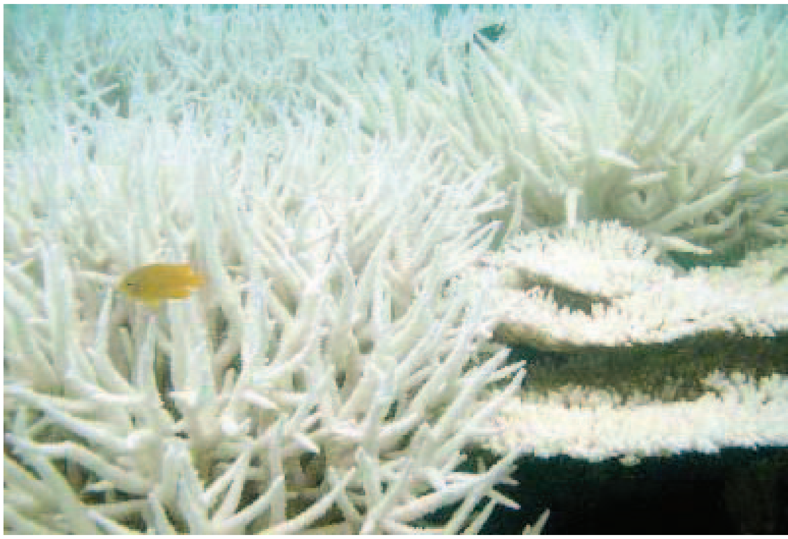
Neoclassical economists do not consider scale an issue, and are unconcerned with throughput. Rather, they focus singularly on efficient allocation.

Ecological economists base their analysis upon the idea that the economy is connected to, and sustained by, a flow of energy, materials, and ecosystem services; i.e. a connection of depletion to pollution by the concept of throughput. Primarily, the impacts upon the entire ecosystem by economic activities that cause depletion, pollution and entropic degradation.

Daly writes that the Earth has a finite amount of matter and energy. Although they are constant in quantity they change in quality, both naturally and as they move through the economic system. Because of this, ecological economists are advocates of metrics that measure the health and stability of the ecosystems beyond an atypical price and exchange value.

"Bleached Coral Reefs." Photo Credits: NOAA





Literature Referenced in General Economic Theory and Overview

Arrow, K.J. (1970). ***Social choice and individual values***. New York: Wiley.

Arrow, K.J. and Debreau, G. (1954). Existence of an equilibrium for a competitive economy. ***Econometrics***, 22, 3-265.

Barro, R.J., Sala-i-Martin, X. (1995). ***Economic Growth.*** McGraw-Hill, New York.

Bator, F. M. (1958). The anatomy of market failure. ***Quarterly Journal of Economics*** 72, no. 3: 351-379

Baumol, W.J. (1967). ***Business behavior, value, and growth***. New York: Macmillan Co.

Conrad, J.M. and C.W. Clark (1989), ***Natural resource economics: notes and problems***. Cambridge: Cambridge University Press.

Costanza, R., Daly, H.E., & Bartholomew, J.A. (1991). ***Ecological economics: the science and mana gement of sustainability***. Columbia University Press.

Cropper, M.L. and Oates, W.E. (1992). ***Environmental economics: a survey. Journal of Economic Literature,*** 30, 2, 675-40.

Daly, H.E. & Farley, J. (2004). ***Ecological Economics***. Washington: Island Press.

Friedman, M. and Savage, L. (1948). The utility analysis of choices involving risk. ***Journal of Political Economy***, 56, 279-304.

Hardin, G. (1968). ***The Tragedy of the Commons***. Science, 162, 1243-1248.

Harris, L. (2003, April 9). The skeptical economist. ***Grist***. Retrieved February 1, 2009, from http://www.grist.org/news/maindish/2003/04/09/the/

Malinvaud, E. (1972). ***Lectures on microeconomic theory***. New York: North-Holland Publishing.

Pareto, V. (1906). ***Manual of Political Economy***. 1971 translation of 1927 edition, New York: Augustus M. Kelley.

Ricardo, D. (1971). ***On the Principles of Political Economy and Taxation***. Harmondsworth: Penguin.

Romer, P.M. (2005). Increasing returns and long-run growth. ***The Journal of Political Economy***, 94, 5, 1002-1037.

Samuelson, P. (1954). "The Pure Theory of Public Expenditure". ***Review of Economics and Statistics***, 36 (4): 387–389.

Samuelson, P. (1983). ***Foundations of economic analysis***. Cambridge and London: Harvard University Press.

Solow, R.M. (1974), The economics of resources or the resources of economics. ***American Economic Review***, 66, 1 - 114.

Stavins, R.N. (2004). Environmental Economics. In L. Blume and S. Durlauf (Eds.). ***The New Palgrave Dictionary of Economics***, 2nd Edition. London: Palgrave Macmillan Ltd.

U.S. Office of Management and Budget, Office of Information and Regulatory Affairs. (1996). Economic Analysis of Federal Regulations Under Executive Order 12866, "Regulatory Planning and Review."

Literature Referenced in Ecological Economics: Theory and History

Costanza, R., Daly, H. E. and Bartholomew, J. A. (1991). ***Goals, agenda and policy recommendations for ecological economics***. New York: Columbia University Press.

Daly, H. (2005). Economics in a full world. ***Scientific American***, 293, 3, 100.

Daly, H. and Townsend, K. (Eds.) (1993). ***Valuing the earth: economics, ecology, ethics***. Cambridge, Mass.; London, England: MIT Press.

Farber, S.C., Costanza, R. and Wilson, M.A. 2002. Economic and ecological concepts for valuing ecosystem services. ***Ecological Economics***, 41: 375-392.

Hawken, P., Lovens, A., and Lovens, H. 1999. ***Natural Capitalism: Creating the Next Industrial Revolution. Rocky Mountain Institute***.

Max-Neef, M. 1995. Economic growth and quality of life: a threshold hypothesis. ***Ecological Economics***, 15: 115-118.

Ruth, M.R. (2006). A quest for the economics of sustainability and the sustainability of economics. ***Ecological Economics***, 56, 332-342.

Sagoff, M. (2004). ***Price, principle and the environment***. Cambridge University Press, Cambridge, England.

Talbarth, J., Cobb, C. & Slattery, N. (2006). ***The Genuine Progress Indicator 2006: a tool for sustainable development, redefining progress***. Oakland, California.

Wackernagel, M., Onisto, L., Bello, P., Callejas, A., Falfán, I., García, J., Guerrero, A., Guerrero, G. (1999). National natural capital accounting with the ecological footprint concept. ***Ecological Economics***, 29: 375-390.

Waggoner, P.E. and Ausubel, J.H. (2002). A framework for sustainability science: a renovated IPAT identity. ***Proceedings of the National Academy of Sciences*** 99: 7860-7865.

Examples of Literature Assessed and Synthesized in Translating Theory into Practice: Tools and Applications

Azar, C. & Sterner, T. (1996). Discounting and distributional concerns in the context of global warming. ***Ecological Economics***, 19, 169-184.

Cobb, C.W., & Cobb, J.B. (1994). ***The green national product: a proposed index of sustainable economic welfare***. Lanham: University Press of America.

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions—a strategy for eco-effective product and system design. ***Journal of Cleaner Production***. 15, 13-14, 1337-1348.

Daly, H.E. (1996). ***Beyond growth: the economics of sustainable development***. Boston: Beacon Press.

England, R.W. (1998). Measurement of social well-being: alternatives to gross domestic product. ***Ecological Economics***, 25, 1,89-103.

Juster, F. T. (1973). A framework for the measurement of economic and social performance. ***In The measurement of economic and social performance***, ed. M Moss. New York: Columbia University Press.

Kiker, G.A., Bridges, T.A., Verghese, A., Seager, T.P., Linkov, I. (2005). Application of multicriteria decision analysis in environmental decision making. ***Integrated Environmental Assessment and Decision Making***.

Lambert, A. & Boons, F. (2002). Eco-industrial parks: stimulating sustainable development in mixed industrial parks. ***Technovation*** 22: 471-484.

Martiniez-Alier, J. & Schlupmann, K. (1999). ***Ecological economics. International Encyclopedia of the Social and Behavioral Sciences***, 4.9, 9.

McDonough, W. & Braungart, M. (2002). ***Cradle to cradle: remaking the way we make things***. North Point Press.

Neumayer, E. (1999). The ISEW-not an index of sustainable economic welfare. ***Social Indicators Research***, 48,1,77-101.

Romero & Rehman. (1987). Management and the use of multiple criteria decision analysis. ***European Review of Agricultural Economics***.

Stahl, C., Cimorelli, A.J. & Chow, A.H. (2002). A new approach to environmental decision analysis: Multi-criteria integrated resource assessment. ***Bulletin of Science, Technology & Society***, 22, 443-459.

Talberth, J., Cobb, C.W., & Slattery, N. (2007). The Genuine Progress Indicator 2006. ***Oakland: Redefining Progress***.

U.S. Office of Management and Budget (1992). ***Circular No. A-94 Revised***. Retrieved December 14, 2009, from http://www.whitehouse.gov/omb/circulars/a094/a094.html#8

Veenhoven, R. (1995). World database of happiness. ***Social Indicators Research***, 34,3,299-313.

Zerbe, R.O. (2007). Ethical Benefit-Cost Analysis. ***ExpressO***.Retrieved February 6, 2009, from http://works.bepress.com/richard_zerbe/3

Zopounidis, C. & Doumpos, A. (2002). Multicriteria classification and sorting methods: A literature review. ***European Journal of Operational Research***.

Additional Readings

Ackerman, F. and Gallgher, K. (2000). ***Getting the prices wrong. Global Development and Environmental Working Paper***.

Armsworth & Roughgarden. (2001). ***An invitation to ecological economics. Trends in Ecology and Evolution***, 2001.

Ayres, R.U. & Ayres, L. (Eds.). (2002). ***A handbook of industrial ecology***. Cheltenham, UK: Edward Elgar.

Costanza, R., Daly, H. E. and Bartholomew, J. A. (1991). ***Goals, agenda and policy recommendations for ecological economics***. New York: Columbia University Press.

Daly, H.E. & Farley, J. (2004). ***Ecological economics***. Washington: Island Press.

Dreborg, K. H. (1996). Essence of backcasting. ***Futures***, 28(9), 813–828.

Flyvbjerg, B., Skamris Holm, M.K., & Buhl, S.L. (2002). Underestimating costs in public works projects: error or lie? ***Journal of the American Planning Association***, 68, 3, 279-295.

Garner, A. (1995). ***Industrial ecology: An introduction***. Ann Arbor, MI: National Pollution Prevention Center for Higher Education.

Gowdy, J.M. & Erickson, J.D. (2004). The approach of ecological economics. New York: Rensselaer ***Working Papers in Economics***.

Holmberg, J. (1998). Backcasting: A natural step in operationalising sustainable development. ***Greener Management International***, Autumn 1998, 30–51.

Holmberg, J., & Robèrt, K.-H. (2000). Backcasting from non-overlapping sustainability principles: a framework for strategic planning. ***International Journal of Sustainable Development and World Ecology***, 7, 291–308.

Kuznets, S. (1941). ***National income and its composition***, 1919–1938. National Bureau of Economic Research, New York.

Lucas, R.E. (1988). On the mechanics of economic development. ***Journal of Monetary Economics***, 22, 3-42.

Marshall, A. (1890). ***Principles of economics***. Amherst, NY: Prometheus Books.

Martinez-Alier, J. (1990). ***Ecological economics: energy, environment and society***. Oxford, England: Basil Blackwell.

Nelson, R.R. and Winer, S.G. (1982). ***An evolutionary theory of economic change***. Cambridge: Harvard University Press.

Norgaard, R.B. (1990), Economic indicators of resource scarcity: a critical essay. ***Journal of Environmental Economics and Management***, 19, 19 - 25.

Pigou, A.C. (1929). ***The economics of welfare***. London: Macmillan and Co.

Robbins, L. (1932). ***An essay on the nature and significance of economic science***. London: Macmillan and Co.

Robèrt, K.-H., Schmidt-Bleek, B., Aloisi de Larderelc, J., Basile, G., Jansen, J. L., & Kuehr, R., et al. (2002). Strategic sustainable development - selection, design and synergies of applied tools. ***Journal of Cleaner Production***, 10(3), 197–214.

Robinson, J. B. (1990). Futures under glass: A recipe for people who hate to predict. ***Futures***, 22(8), 820–842.

Ruth, M. (1993). ***Integrating economics, ecology and thermodynamics***. Dortrecht, The Netherlands: Kluwer Academic Publishers.

Schumpeter, J.A. (1994). ***History of economic analysis***. New York: Oxford University Press.

Williamson, O.E. (1987). ***The economic institutions of capitalism***. New York: Free Press.

Wittmer, H, Rauchmeyer, F, & Klauer, B. (2006). ***How to select instruments for resolution of environmental conflicts? Land Use Policy***.

Ayres, R.U. & Ayres, L. (Eds.). (2002). ***A handbook of industrial ecology***. Cheltenham, UK: Edward Elgar.

Costanza, R., Daly, H. E. and Bartholomew, J. A. (1991). ***Goals, agenda and policy recommendations for ecological economics***. New York: Columbia University Press.

Daly, H.E. & Farley, J. (2004). ***Ecological economics***. Washington: Island Press.

Dreborg, K. H. (1996). Essence of backcasting. ***Futures***, 28(9), 813–828.

Flyvbjerg, B., Skamris Holm, M.K., & Buhl, S.L. (2002). Underestimating costs in public works projects: error or lie? ***Journal of the American Planning Association***, 68, 3, 279-295.

Garner, A. (1995). ***Industrial ecology: An introduction***. Ann Arbor, MI: National Pollution Prevention Center for Higher Education.

Gowdy, J.M. & Erickson, J.D. (2004). The approach of ecological economics. New York: Rensselaer ***Working Papers in Economics***.

Holmberg, J. (1998). Backcasting: A natural step in operationalising sustainable development. ***Greener Management International***, Autumn 1998, 30–51.

Holmberg, J., & Robèrt, K.-H. (2000). Backcasting from non-overlapping sustainability principles: a framework for strategic planning. ***International Journal of Sustainable Development and World Ecology***, 7, 291–308.

Kuznets, S. (1941). ***National income and its composition***, 1919–1938. National Bureau of Economic Research, New York.

Lucas, R.E. (1988). On the mechanics of economic development. ***Journal of Monetary Economics***, 22, 3-42.

Marshall, A. (1890). ***Principles of economics***. Amherst, NY: Prometheus Books.

Martinez-Alier, J. (1990). ***Ecological economics: energy, environment and society***. Oxford, England: Basil Blackwell.

Nelson, R.R. and Winer, S.G. (1982). ***An evolutionary theory of economic change***. Cambridge: Harvard University Press.

Norgaard, R.B. (1990), Economic indicators of resource scarcity: a critical essay. ***Journal of Environmental Economics and Management***, 19, 19 - 25.

Pigou, A.C. (1929). ***The economics of welfare***. London: Macmillan and Co.

Robbins, L. (1932). ***An essay on the nature and significance of economic science***. London: Macmillan and Co.

Robèrt, K.-H., Schmidt-Bleek, B., Aloisi de Larderelc, J., Basile, G., Jansen, J. L., & Kuehr, R., et al. (2002). Strategic sustainable development - selection, design and synergies of applied tools. ***Journal of Cleaner Production***, 10(3), 197–214.

Robinson, J. B. (1990). Futures under glass: A recipe for people who hate to predict. ***Futures***, 22(8), 820–842.

Ruth, M. (1993). ***Integrating economics, ecology and thermodynamics***. Dortrecht, The Netherlands: Kluwer Academic Publishers.

Schumpeter, J.A. (1994). ***History of economic analysis***. New York: Oxford University Press.

Williamson, O.E. (1987). ***The economic institutions of capitalism***. New York: Free Press.

Wittmer, H, Rauchmeyer, F, & Klauer, B. (2006). ***How to select instruments for resolution of environmental conflicts? Land Use Policy***.

additional readings

- Allocation, Distribution, and Scale
- Cost-Benefit Analysis
- Development
- Discounting
- Ecological Economic Theory
- Economic Growth
- Economic Indicators
- Ethics
- History of Ecological Economics
- Industry
- Life Cycle Assessments
- Methodology
- Multi Criteria Analysis
- Technology
- Thermodynamics
- Throughput
- Valuing Environmental Goods and Services

additional readings in economics

This appendix provides a brief listing of pertinent literature that will serve for more in-depth reading of the concepts that are addressed within the main text and its appendices.

Allocation, Distribution, and Scale

Ackerman, F. (2002). ***Still Dead After All These Years: Interpreting the Failure of General Equilibrium Theory.*** Global Development and Environment Institute Working Paper 00-01.
This article discusses the failure of general equilibrium theory. Cited by 37.

Barry, B. (1983). Intergenerational Justice in Energy Policy. In D. MacLean & P.G. Brown, (Eds.). ***Energy and the Future*** (pp. 15-30). Totowa, NJ: Rowman and Littlefield.
Compensation of future generations by the present generation for exhausting natural resources is proposed. Cited by 31.

Beltratti, A., Chichilnisky, G., & Heal, G. (1995). Sustainable Growth and the Green Golden Rule. In I. Goldwin & L.A. Winters (Eds.). ***The Economics of Sustainable Development.*** Cambridge, England: Cambridge University Press.
This chapter analyzes the environmental implications of continued economic growth. Cited by 49.

Boulding, K.E. (1966). The Economics of the Coming Spaceship Earth. In H. Jarrett (Ed.). ***Environmental Quality in a Growing Economy*** (pp. 3-14). Baltimore: Johns Hopkins Press.
The planet's finite space and resources, and its implications for economics, is explored. Cited by 760.

Burness, S., Cummings, R., Morris, G., & Paik, I. (1980). Thermodynamic and Economic Concepts as Related to Resource-Use Policies. ***Land Economics,*** 56, 1-9.
Market-based solutions to resource scarcity are discussed. Cited by 21.

Common, M. & Perrings, C. (1992). Toward an Ecological Economics of Sustainability. ***Ecological Economics,*** 6, 7-34.
A model is developed which includes both economic and ecological concepts of sustainability. Cited by 234.

Costanza, R. (1991). ***Ecological Economics: The Science and Management of Sustainability***. New York: Columbia University Press.
This book explains the theory and methods of ecological economics. Cited by 557.

Costanza, R. & Daly, H.E. (1987) Toward an Ecological Economics. ***Ecological Modeling,*** 38, 1-7.
This article argues that humanity's increasing impact on the environment requires a convergence of the disciplines of ecology and economics. Cited by 50.

Daly, H.E. (1987). The Economic Growth Debate: What Some Economists Have Learned but Many Have Not. ***Journal of Environmental Economics and Management,*** 14, 323-336.
The distinction between growth and development is examined, as well as the perils of a growth-oriented economy. Cited by 101.

Daly, H.E. (1992). Allocation, Distribution, and Scale: Towards an Economics That Is Efficient, Just, and Sustainable. ***Ecological Economics,*** 6, 185-193.
This article discusses the goals of an economic system and ways to achieve them. Cited by 231.

Daly, H.E. (1993). Introduction to the Steady-State Economy. In H.E. Daly & K. Townsend (Eds.). ***Valuing the Earth: Economics Ecology, Ethics (***pp. 1-31)*.* Cambridge, MA and London: MIT Press.
This article explains the paradigm shift presented by ecological economics. Cited by 24.

Daly, H.E. (2003). ***Ecological Economics: The Concept of Scale and its Relationship to Allocation, Distribution, and Uneconomic Growth***. For CANSEE, Oct. 16-19 2003.
This article summarizes the main points of ecological economics and explores the limits to economic growth. Cited by 6.

Daly, H.E. & Farley, J. (2003). ***Ecological Economics: Principles and Applications.*** Washington, D.C. and Covelo, CA: Island Press.
This book explains the theory and policy goals of ecological economics. Cited by 167.

Daly, H.E. (2005). Economics in a Full World. ***Scientific American,*** 293, 3.
This article explains the economy's relationship to the ecosystem and why limitless economic growth is impossible. Cited by 32.

Dixon, J.A. and Fallon, L.A. (1989). The Concept of Sustainability: Origins, Extensions, and Usefulness for Policy. ***Society and Natural Resources,*** 2, 73-84.
This article provides some definitions of sustainable development terminology in an effort to alleviate some ambiguity in the field. Cited by 78.

Engel, J.R. (1990). Introduction: The Ethics of Sustainable Development. In J.R. Engel & J.G. Engel (Eds.). ***Ethics of Environment and Development: Global Challenge, International Response*** (pp. 1-23). London: Belhaven Press.
This article explores the implications of holding sustainable development as a global ethic. Cited by 35.

Foy, G. & Daly, H.E. (1989). ***Allocation, Distribution, and Scale as Determinants of Environmenal Degradation: Case Studies of Haiti, El Salvador, and Costa Rica***. World Bank Environment Department Working Paper No. 19.
Case studies show three causes of environmental problems in Haiti. Cited by 42.

Georgescu-Roegen, N. (1975). Selections from "Energy and Economic Myths." ***Southern Economic Journal,*** 41.
This article outlines some economic principles that are inconsistent with the laws of physics. Cited by 14.

Goodland, R., Daly, H.E., & El Serafy, S., (Eds.). (1992). ***Population, Technology, and Lifestyle.*** Washington, D.C. and Covelo, California: Island Press.
This book explores the implications of creating a sustainable world. Cited by 51.

Gowdy, J.M. (2000). Terms and Concepts in Ecological Economics***. Wildlife Society Bulletin ,*** 26-33.
Sustainability is defined in the context of ecological economics. Cited by 25.

Gowdy, J.M. & Erickson, J.D. (2004). ***Ecological Economics at a Crossroads.*** Rensselaer Working Papers in Economics: Troy, NY.
This paper looks at the points where ecological economics conflicts with neoclassical economics. Cited by 17.

Gowdy, J.M. & Erickson, J.D. (2005). ***The Approach of Ecological Economics.*** Rensselaer Working Papers in Economics: Troy, NY.
This paper explores the major tenets of ecological economics. Cited by 23.

Guha, R. (1989). Radical American Environmentalism and Wilderness Preservation: A Third World Critique. ***Environmental Ethics,*** 11, 71-83.
The deep ecology movement is criticized as a uniquely American phenomenon that doesn't account for the needs of people worldwide. Cited by 210.

Hannon, B. (1977). Energy, Labor, and the Conserver Society. ***Technology Review,*** March/April 1977, 47-53.
The United States' energy options are explored. Cited by 4.

Harris, J.M. (1991). Global Institutions and Ecological Crisis. ***World Development,*** 19, 111-122.
This article examines the capacity of global institutions to handle ecological degradation. Cited by 10.

Harrison, P. (1992). ***The Third Revolution: Environment, Population and a Sustainable World***. London and New York: I.B. Tauris & Co. Ltd.
This book looks at growth in the human population and its environmental implications. Cited by 72.

Holmberg, J. (1992). ***Making Development Sustainable.*** Washington, D.C. and Covelo, California: Island Press.
Sustainable development and its issues are analyzed. Cited by 32.

Homer-Dixon, T.F., Boutwell, J.H., & Rathjens, G.W. (1993). ***Scientific American,*** 268, 38-45. Population and consumption impose a strain on our natural resources that is increasing worldwide violent conflict. Cited by 192.

Lele, S.M. (1991). Sustainable Development: A Critical Review. ***World Development,*** 19, 607-621.
This article criticizes the vagueness in sustainable development literature. Cited by 505.

Norgaard, R. (1988). Sustainable Development. ***Futures,*** Dec. 1988, 606-620.
Challenges and themes in sustainable development are explored. Cited by 109.

Norgaard, R. & Howarth, R. (1992). Economics, Ethics, and the Environment. In J.M. Hollander (Ed.). ***The Energy-Environment Connection*** (pp. 347-363). Washington, D.C. and Covelo, CA: Island Press.
This article explores the impacts of the economy on future generations and the ethical issues therein. Cited by 8.

Pearce, D. (1987) Foundations of Ecological Economics. ***Ecological Modeling,*** 38, 9-18.
This article argues that ecological economics should employ a Rawlsian concept of distributive justice in defining sustainability. Cited by 59.

Schwarze, R., Deutsch, M., Krysiak, D., & Stewart, L.H. (2003). ***Intergenerational Justice and Sustainability.*** Background paper for an expert workshop at the DIW Berlin.
This paper explores the relationship between intergenerational justice and sustainability. Cited by 2.

Shiva, V. (1992). Recovering the Real Meaning of Sustainability. In D. Cooper and J.S. Paler (Eds.). ***The Environment in Question.*** New York: Routledge.
The meaning of sustainability and its implications for economic growth are investigated. Cited by 37.

Toman, M.A. (1992). The Difficulty in Defining Sustainability. ***Resources,*** 106, 3-6.
The multiple meanings of sustainability are reviewed. Cited by 62.

Underwood, D.A. & King, P.G. (1989). On the Ideological Foundations of Environmental Policy. ***Ecological Economics,*** 1, 315-334.
The philosophical differences between neoclassical and steady-state economics are explored. Cited by 18.

Williams, J.B., & McNeill, J.M. (2005). ***The Current Crisis in Neoclassical Economics and the Case for an Economic Analysis Based on Sustainable Development.*** U21Global Working Paper.
This paper talks about the failures of neoclassical economics and the paradigm shift in ecological economics. Cited by 1.

Young, J.T. (1991). Is the Entropy Law Relevant to the Economics of Natural Resource Scarcity? ***Journal of Environmental Economics and Management,*** 21, 169-179.
The application of thermodynamics to economics is questioned. Cited by 42.

Cost-Benefit Analysis

Ackerman, F., & Gallagher, K. (2000). ***Getting the Prices Wrong: The Limits of Market-Based Environmental Policy.*** Global Development and Environment Institute Working Paper 00-05.
This article questions the efficacy of market-based environmental policy. Cited by 5.

Ackerman, F., Heinzerling, L., & Massey, R. (2004). ***Applying Cost-Benefit Analysis to Past Decisions: Was Protecting the Environment Ever a Good Idea?*** Center for Progressive Regulation White Paper.
This article gives case studies of successful policies that do not pass cost-benefit tests. Cited by 3.

Johansson, P. (1990). Valuing Environmental Damage. ***Oxford Review of Economic Policy,*** 6, 34-50.
This article discusses methods for valuing environmental degradation. Cited by 60.

Sagoff, M. (1988). Some Problems with Environmental Economics. ***Environmental Ethics,*** 10, 55-74.
This article criticizes methods for pricing environmental goods and services utilized by environmental economists. Cited by 56.

Development

Engel, J.R. (1990). Introduction: The Ethics of Sustainable Development. In J.R. Engel & J.G. Engel (Eds.). ***Ethics of Environment and Development: Global Challenge, International Response*** (pp. 1-23). London: Belhaven Press.
This article explores the implications of holding sustainable development as a global ethic. Cited by 35.

Goodland, R. & Daly, H.E. (1992). Ten Reasons Why Northern Income Growth Is Not the Solution to Southern Poverty. In R. Goodland, H.E. Daly, & S. El Serafy (Eds.). ***Population, Technology, and Lifestyle: The Transition to Sustainability*** (pp. 128-145). Washington, D.C. and Covelo, CA: Island Press.
The idea that Southern poverty alleviation depends on Northern economic growth is criticized and alternative recommendations are offered. Cited by 50.

Guha, R. (1989). Radical American Environmentalism and Wilderness Preservation: A Third World Critique. ***Environmental Ethics,*** 11, 71-83.
The deep ecology movement is criticized as a uniquely American phenomenon that doesn't account for the needs of people worldwide. Cited by 210.

Harris, J.M. (1991). Global Institutions and Ecological Crisis. ***World Development,*** 19, 111-122.
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Holmberg, J. (1992). ***Making Development Sustainable.*** Washington, D.C. and Covelo, California: Island Press.
Sustainable development and its issues are analyzed. Cited by 32.

Homer-Dixon, T.F., Boutwell, J.H., & Rathjens, G.W. (1993). ***Scientific American,*** 268, 38-45. Population and consumption impose a strain on our natural resources that is increasing worldwide violent conflict. Cited by 192.

Norgaard, R. (1987). Economics as Mechanics and the Demise of Biological Diversity. ***Ecological Modeling,*** 38, 107-121.
This article explains how widespread social and economic trends have impacted biodiversity. Cited by 25.

Shiva, V. (1992). Recovering the Real Meaning of Sustainability. In D. Cooper and J.S. Paler (Eds.). ***The Environment in Question.*** New York: Routledge.
The meaning of sustainability and its implications for economic growth are investigated. Cited by 37.

Soderbaum, P. (1992). Neoclassical and Institutional Approaches to Development and the Environment. ***Ecological Economics,*** 5, 127-144.
The environmental implications of different economic paradigms are examined. Cited by 31.

Discounting

Costanza, R. & Daly, H.E. (1987) Toward an Ecological Economics. ***Ecological Modeling,*** 38, 1-7.
This article argues that humanity's increasing impact on the environment requires a convergence of the disciplines of ecology and economics. Cited by 50.

Markandya, A. & Pearc, D. Development, the Environment, and the Social Rate of Discount. ***The World Bank Research Observer,*** 6, 137-152.
This article critiques the use of discounting applied to natural resources and examines policy alternatives. Cited by 56.

Norgaard, R. & Howarth, R. (1992). Economics, Ethics, and the Environment. In J.M. Hollander (Ed.). ***The Energy-Environment Connection*** (pp. 347-363). Washington, D.C. and Covelo, CA: Island Press.
This article explores the impacts of the economy on future generations and the ethical issues therein. Cited by 8.

Page, T. (1983). Intergenerational Justice as Opportunity. In D. MacLean & P.G. Brown (Eds.). ***Energy and the Future*** (pp. 38-58). Totowa, NJ: Rowman and Littlefield.
This article examines discounting in the context of two ethical frameworks. Cited by 51.

Perrings, C. (1991). Reserved Rationality and the Precautionary Principle: Technological Chane, Time, and Uncertainty in Environmental Decision Making. In R. Costanza (Ed.). ***Ecological Economics: The Science and Management of Sustainability*** (pp.153-166). New York: Columbia University Press.
Considerations of uncertainty, and its impact on environmental policy, are discussed. Cited by 99.

Ecological Economic Theory

Ackerman, F. (2002). ***Still Dead After All These Years: Interpreting the Failure of General Equilibrium Theory.*** Global Development and Environment Institute Working Paper 00-01.
This article discusses the failure of general equilibrium theory. Cited by 37.

Armsworth, P.A., & Roughgarden, J.E. (2001). An Invitation to Ecological Economics. ***TRENDS in Ecology and Evolution,*** 16, 5, 229-234.
The isbenefits of ecological economics to other fields, such as biology, are explored. Cited by 21.

Barbier, E.B. (1990). Alternative Approaches to Economic-Environmental Interactions. ***Ecological Economics,*** 2, 7-26.
This article explores the economic valuation of environmental goods and services. Cited by 27.

Common, M. & Perrings, C. (1992). Toward an Ecological Economics of Sustainability. ***Ecological Economics,*** 6, 7-34.
A model is developed which includes both economic and ecological concepts of sustainability. Cited by 234.

Costanza, R., Daly, H.E., & Bartholomew, J.E. (1991). Goals, Agenda, and Policy Recommendations for Ecological Economics. In R. Costanza (Ed.). ***Ecological Economics: The Science and Management of Sustainability*** (pp. 1-19). New York: Columbia University Press.
This chapter summarizes the goals of ecological economics and provides some policy recommendations. Cited by 203.

Daly, H.E. (1968). On Economics as a Life Science. ***Journal of Political Economy,*** 76, 392-406.
The contributions of biology to economics, and vice versa, are explained. Cited by 204.

Daly, H.E. (1993). Introduction to the Steady-State Economy. In H.E. Daly & K. Townsend (Eds.). ***Valuing the Earth: Economics Ecology, Ethics (***pp. 1-31)*.* Cambridge, MA and London: MIT Press.
This article explains the paradigm shift presented by ecological economics. Cited by 24.

Daly, H.E. & Farley, J. (2003). ***Ecological Economics: Principles and Applications.*** Washington, D.C. and Covelo, CA: Island Press.
This book explains the theory and policy goals of ecological economics. Cited by 167.

Georgescu-Roegen, N. (1986). The Entropy Law and the Economic Process in Retrospect. ***Eastern Economic Journal,*** 12, 3-25.
This article discusses the second law of thermodynamics' application to the economy. Cited by 48.

Gowdy, J.M. (2000). Terms and Concepts in Ecological Economics***. Wildlife Society Bulletin,*** 26-33.
Sustainability is defined in the context of ecological economics. Cited by 25.

Gowdy, J.M. & Erickson, J.D. (2004). ***Ecological Economics at a Crossroads.*** Rensselaer Working Papers in Economics: Troy, NY.
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This article explores the impacts of the economy on future generations and the ethical issues therein. Cited by 8.

Peet, J. (1992). The Biophysical Systems World View. In ***Energy and the Ecological Economics of Sustainability,*** (pp. 83-95). Washington, D.C. and Covelo, CA: Island Press.
This article compares the biophysical systems perspective and the political-economic perspective of economic analysis. Cited by 99.

Ruth, M. 1993. ***Integrating Economics, Ecology and Thermodynamics***, Kluwer Academic Publishers, Dortrecht, The Netherlands, 251 pp.
Presents the foundations of Ecological Economics, summarizes ongoing research and lays out future directions. Cited by 109.

Soderbaum, P. (1992). Neoclassical and Institutional Approaches to Development and the Environment. ***Ecological Economics,*** 5, 127-144.
The environmental implications of different economic paradigms are examined. Cited by 31.

Underwood, D.A. & King, P.G. (1989). On the Ideological Foundations of Environmental Policy. ***Ecological Economics,*** 1, 315-334.
The philosophical differences between neoclassical and steady-state economics are explored. Cited by 18.

Economic Growth

Daly, H.E. (1987). The Economic Growth Debate: What Some Economists Have Learned but Many Have Not. ***Journal of Environmental Economics and Management,*** 14, 323-336.
The distinction between growth and development is examined, as well as the perils of a growth-oriented economy. Cited by 101.

Daly, H.E., & Townsend, K.N. (1993). ***Valuing the Earth: Economics, Ecology, Ethics.*** Cambridge, MIT Press.
This explores the relationship of human beings, and economic activity, to the natural word. Cited by 104.

Goodland, R., Daly, H.E., & El Serafy, S., (Eds.). (1992). ***Population, Technology, and Lifestyle.*** Washington, D.C. and Covelo, California: Island Press.
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Lele, S.M. (1991). Sustainable Development: A Critical Review. ***World Development,*** 19, 607-621.
This article criticizes the vagueness in sustainable development literature. Cited by 505.

Norgaard, R. (1988). Sustainable Development. ***Futures,*** Dec. 1988, 606-620.
Challenges and themes in sustainable development are explored. Cited by 109.

Ruth, M. 2006. The Economics of Sustainability and the Sustainability of Economics, ***Ecological Economics***, Vol. 56, No. 3, pp. 332-342.
Compares resource and environmental economics with ecological economics through the lens of economic growth theory. Cited by 13.

Trainer, F.E. (1990). Environmental Significance of Development Theory. ***Ecological Economics,*** 2, 277-286.
The impact of economic growth and ecological damage on global wellbeing is analyzed. Cited by 14.
This article defines industrial ecology and examines some of the issues of the field. Cited by 28.

Economic Indicators

El Serafy, S. & Lutz, E. (1989). Environmental and Resource Accounting: An Overview. In Y.J. Ahmad, S. El Serafy, & E. Lutz (Eds.). ***Environmental Accounting for Sustainable Development***, (pp. 1-7). Washington, D.C.: The World Bank.
This article questions mainstream economists' treatment of industrial wastes as externalities, arguing that costs of ecosystem degradation should be internalized. Cited by 28.

Georgescu-Roegen, N. (1979). Energy Analysis and Economic Valuation. ***Southern Economic Journal***, 45, 1023-1058.
The idea that energy is the only source of value is examined, with the critique that "matter matters too." Cited by 80.

Heal, G. & Barbier, E. (2006). Valuing Ecosystem Services. ***Economist's Voice***, January 2006.
This article explores the issues inherent in pricing environmental goods and services. Cited by 79.

Hueting, R. (1991). Correcting National Income for Environmental Losses: A Practical Solution for a Theoretical Dilemma. In R. Costanza (Ed.). ***Ecological Economics: The Science and Management of Sustainability*** (pp. 194-213). New York: Columbia University Press.
This article questions the use of growth as a measure of economic progress and explores the dilemma of pricing ecosystem services. Cited by 66.

Norgaard, R. (1989). Three Dilemmas of Environmental Accounting. ***Ecological Economics***, 1, 303-314.
This article criticizes that current measures of national income fail to include the value of environmental systems, and points out the logical inconsistencies in attempting to price environmental goods and services. Cited by 39.

Norgaard, R.B. (1990). Economic Indicators of Resource Scarcity: A Critical Essay. ***Journal of Environmental Economics and Management***, 19, 19-25. Literature discussing indicators of long-term scarcity is reviewed and critiqued. Cited by 96.

Peskin, H, & Lutz, E. (1993). A Survey of Resource and Environmental Accounting in Industrialized Countries. In E. Lutz, ***Toward Improved Accounting for the Environment***. Washington, D.C.: World Bank.
Existing measures of economic progress fail to reflect changes in environmental health or natural resource stocks, and thus do not provide an accurate picture of national wealth. Cited by 40.

Ruth, M. (1993). ***Integrating Economics, Ecology and Thermodynamics***, Kluwer Academic Publishers, Dortrecht, The Netherlands, 251 pp.
Presents the foundations of Ecological Economics, summarizes ongoing research and lays out future directions. Cited by 109.

Slesser, M. (1989). Toward an Exact Human Ecology. In P.J. Grubb & J.B. Whittaker (Eds.). ***Toward a More Exact Ecology*** (423-436). Oxford, England and Cambridge, MA: Blackwell Books.
This article explains the interrelated nature of the economy and the environment and explores a procedure called natural capital accounting, which uses embodied energy to calculate the economy's environmental impact. Cited by 2.

Tinbergen, J. & Hueting, R. (1992). GNP and Market Prices: Wrong Signals for Sustainable Economic Success That Mask Environmental Destruction. In R. Goodland, H.E. Daly, & S. El Serafy (Eds.). ***Population, Technology, and Lifestyle: The Transition to Sustainability*** (pp. 52-62). Washington, D.C. and Covelo, CA: Island Press.
This article argues that a genuine measure of national income ought to include a measure of environmental health. GNP growth, coupled with environmental destruction, can have a negative impact on welfare. Cited by 36.

Ethics

Callicot, J.B. (1993). The Search for an Environmental Ethic. In T. Regan (Ed.). ***Matters of Life and Death: New Introductory Essays in Moral Philosophy, 3rd edition*** (pp. 322-382). New York: McGraw-Hill.
This article examines the existing schools of environmental ethics and argues the need for a new approach. Cited by 29.

Norgaard, R. & Howarth, R. (1992). Economics, Ethics, and the Environment. In J.M. Hollander (Ed.). ***The Energy-Environment Connection*** (pp. 347-363). Washington, D.C. and Covelo, CA: Island Press.
This article explores the impacts of the economy on future generations and the ethical issues therein. Cited by 8.

Pearce, D. (1987) Foundations of Ecological Economics. ***Ecological Modeling,*** 38, 9-18.
This article argues that ecological economics should employ a Rawlsian concept of distributive justice in defining sustainability. Cited by 59.

History of Ecological Economics

Christensen, P.P. (1989). Historical Roots for Ecological Economics-- Biophysical Versus Allocative Approaches. ***Ecological Economics***, 1, 17-36.
This article explains the intellectual roots of ecological economics by providing a history of economic theory. Cited by 97.

Cleveland, C.J. (1987). Biophysical Economics: Historical Perspective and Current Research Trends. ***Ecological Modeling***, 38, 47-73. Biophysical economics, the idea that natural resources play a crucial role in human economies, is explored. Cited by 56.

Faber, M. & Proops, J.L.R. (1985). ***Interdisciplinary Research Between Economists and Physical Scientists: Retrospect and Prospect***. Kyklos, 38, 599-616.
The benefits and drawbacks of cooperation between physical scientists and economists are explored. Cited by 18.

Goodland, R., Daly, H.E., & El Serafy, S., (Eds.). (1992). ***Population, Technology, and Lifestyle.*** Washington, D.C. and Covelo, California: Island Press.
This book explores the implications of creating a sustainable world. Cited by 51.

Harrison, P. (1992). ***The Third Revolution: Environment, Population and a Sustainable World***. London and New York: I.B. Tauris & Co. Ltd.
This book looks at growth in the human population and its environmental implications. Cited by 72.

Judson, D.H. (1989). The Convergence of Neo-Ricardian and Embodied Energy Theories of Value and Price. ***Ecological Economics***, 1, 261-281.
The classical foundations of ecological economics, including energy theory and neo-Ricardian theory, are analyzed. Cited by 12.

Kaufman, R. (1987). Biophysical and Marxist Economics: Learning from Each Other. ***Ecological Modeling***, 38, 91-105.
This article critiques the Marxist rejection of biophysical analysis of production. Cited by 6. Martinez-Alier, J. &

Schlupmann, K. (1987). ***Ecological Economics: Energy, Environment and Society***. Blackwell Books, Oxford, England and Cambridge, Massachusetts.
The applicability of using energy flows to explain the economic system is investigated. Cited by 391.

Mirowski, P. (1988). ***Energy and Energetics in Economic Theory: A Review Essay. Journal of Economic Issues, XXII, 81-830***.
This article explores the theory that energy is the origin of economic value. Cited by 19.

Pearce, D. (1987) Foundations of Ecological Economics. ***Ecological Modeling***, 38, 9-18. This article argues that ecological economics should employ a Rawlsian concept of distributive justice in defining sustainability. Cited by 59.

Richards, J.F. (1986). ***World Environmental History and Economic Development***. In W.C. Clark & R.E. Munn (Eds.). Sustainable Development of the Biosphere. (pp.53-74). New York and Cambridge, England: Cambridge University Press.
The relationship between environmental change and economic activity is examined. Cited by 18.

Ruth, M. 1993. ***Integrating Economics, Ecology and Thermodynamics***, Kluwer Academic Publishers, Dortrecht, The Netherlands, 251 pp.
Presents the foundations of Ecological Economics, summarizes ongoing research and lays out future directions. Cited by 109.

Ruth, M. 2006. The Economics of Sustainability and the Sustainability of Economics, ***Ecological Economics***, Vol. 56, No. 3, pp. 332-342.
Compares resource and environmental economics with ecological economics through the lens of economic growth theory. Cited by 13.

Smith, G.A. (1993). The Teleological View of Wealth: A Historical Perspective. In H.E. Daly & K. Townsend, (Eds.). ***Valuing the Earth: Economics, Ecology, Ethics***. (pp.215-237). Cambridge, MA and London: The MIT Press.
The history of pursuing wealth for its own sake is examined. Cited by 4.

Trainer, F.E. (1990). Environmental Significance of Development Theory. ***Ecological Economics***, 2, 277-286.
The impact of economic growth and ecological damage on global wellbeing is analyzed. Cited by 14.

White, L. (1967). ***The Historical Roots of Our Ecological Crisis. Science***, 155, 1203-1207.
This article provides a historical outlook on humanity's relationship with its environment. Cited by 754.

Industry

Ruth, M. 1998. Energy Use and CO2 Emissions in a Dematerializing Economy: Examples from Five US Metals Sectors, Resources Policy, Vol. 24, pp. 1 - 18. Cited by 9.

Ruth, M. and T. Harrington. 1997. ***Dynamics of Material and Energy Use in US Pulp and Paper Manufacturing, Industrial Ecology***, Vol. 1, pp. 147 - 168.
Presents process-based technology and policy assessment for the US pulp and paper industry. Cited by 24.

Tomer, J. (1992). The Human Firm in the Natural Environment: A Socio-Economic Analysis of Its Behavior. ***Ecological Economics***, 6, 119-138.
Private sector adaptation to environmental degradation and increasing government regulation is discussed. Cited by 19.

Life Cycle Assessments

Ausubel, J.H. (1992). ***Industrial Ecology: Reflections on a Colloquium***. Proceedings of the National Academy of Sciences, 89, 879-884.
This article defines industrial ecology and examines some of the issues of the field. Cited by 28.

Ayres, R. (1989). Industrial Metabolism. In J.H. Ausubel & H.E. Sladovitch (Eds.). ***Technology and Environment*** (pp.23-49). Washington, D.C.: National Academy Press.
The benefits of industry mimicking biological processes are discussed. Cited by 342.

Chapman, P.F. (1974). Energy Costs: A Review of Methods. ***Energy Policy***, 2, 91-103.
The contribution of energy cost analysis to economic decision-making is reviewed. Cited by 44.

Ruth, M. 1998. Mensch and Mesh: Perspectives on Industrial Ecology, ***Journal of Industrial Ecology***, Vol. 2, pp. 13 - 22.
Explores opportunities to close material cycles and reduce environmental impact of economic processes. Cited by 6.

Methodology

Cleveland, C.J. and M. Ruth. 1999. ***Indicators of Dematerialization and the Materials Intensity of Use, Journal of Industrial Ecology***, Vol. 2, pp. 15 – 50.
Explores how to measure and interpret measures of dematerialization and decarbonization of the economy. Cited by 110.

Costanza, R. and M. Ruth. 1998. Using Dynamic Modeling to Scope Environmental Problems and Build Consensus, ***Environmental Management***, Vol. 22, pp. 183 - 196.
Presents dynamic modeling approaches as a means to promote sustainable development. Cited by 121.

Faber, M. & Proops, J.L.R. (1985). ***Interdisciplinary Research Between Economists and Physical Scientists: Retrospect and Prospect***. Kyklos, 38, 599-616.
The benefits and drawbacks of cooperation between physical scientists and economists are explored. Cited by 18.

Norgaard, R. (1989). The Case for Methodological Pluralism. Ecological Economics, 1, 37-57. ***Ecological economics*** is an interdisciplinary field and subject areas that it borrows from can have conflicting methodologies.
This article argues that ecological economics should, at its onset, employ multiple empirical methods. Cited by 148.

Shorgren, J.F. & Nowell, C. (1992). Economics and Ecology: A Comparison of Experimental Methodologies and Philosophies. ***Ecological Economics***, 5, 101-126.
This paper explores the different methods of experimentation and epistemological visions employed by ecology and environmental economics. Cited by 15.

Multi Criteria Analysis

Costanza, R. and M. Ruth. 1998. Using Dynamic Modeling to Scope Environmental Problems and Build Consensus, ***Environmental Management***, Vol. 22, pp. 183 - 196.
Presents dynamic modeling approaches as a means to promote sustainable development. Cited by 121.

Funtowicz, S.O. & Ravetz, J.R. (1994). The Worth of a Songbird: Ecological Economics as a Post-Normal Science. ***Ecological Economics***, 10, 197-207.
Non-quantitative methods of decision-making are examined as a means of evaluating ethically complex issues. Cited by 231.

Nijkamp, P., P. Rietveld and H. Voogd (1990) Multicriteria evaluation in physical planning, Amsterdam, Netherlands; New York: North-Holland; New York, N.Y., U.S.A.: Distributors for the U.S. and Canada, Elsevier Science Publishers.
Presents the methods and used of multicriteria analysis for planning and environmental investment and policy making. Cited by 226.

Technology

Dung, T.H. (1992). ***Consumption, Production, and Technological Progress: Unified Entropic Approach. Ecological Economics***, 6, 195-210.
This article reviews the application of the second law of thermodynamics to economic analyses. Cited by 9.

Jaffe, A.B., Newell, R.G., & Stavins, R.N. (2001). Technological Change and the Environment. In K.G. Maler & J.R. Vincent (Eds.). ***Handbook of Environmental Economics, Volume 1***. Elsevier Science B.V.
The appropriate treatment of technology in environmental policy is discussed. Cited by 266.

Krutilla, J. (1967). Conservation Reconsidered. ***American Economic Review***, 57, 777-789. This article questions whether technological progress can make up for the depletion of resources. Cited by 748.

Perrings, C. (1991). ***Reserved Rationality and the Precautionary Principle: Technological Change, Time, and Uncertainty in Environmental Decision Making***. In R. Costanza (Ed.). ***Ecological Economics: The Science and Management of Sustainability*** (pp.153-166). New York: Columbia University Press.
Considerations of uncertainty, and its impact on environmental policy, are discussed. Cited by 99.

Ruth, M. and C.W. Bullard. 1993. ***Information, Production, and Utility, Energy Policy***, Vol. 21, No. 10, pp. 1059 – 1066.
Presents methods to evaluate model and manage environmental impact of technology. Cited by 13.

Thermodynamics

Ayres, R. & Nair, I. (1984). Thermodynamics and Economics. ***Physics Today***, 37, 62-71.
This article explains the application of thermodynamics to economics and the manufacturing process. Cited by 49.

Burness, S., Cummings, R., Morris, G., & Paik, I. (1980). ***Thermodynamic and Economic Concepts as Related to Resource-Use Policies. Land Economics***, 56, 1-9.
Market-based solutions to resource scarcity are discussed. Cited by 21.

Chapman, P.F. (1974). Energy Costs: A Review of Methods. ***Energy Policy,*** 2, 91-103.
The contribution of energy cost analysis to economic decision-making is reviewed. Cited by 44.

Cleveland, C.J., Costanza, R., Hall, C.A.S., & Kaufman, R. (1984). Energy and the U.S. Economy: A Biophysical Perspective. ***Science***, 225, 890-897.
This article looks at the physical constraints on economic production. Cited by 186.

Cleveland, C.J. and M. Ruth. 1997. When, Where and By How Much Does Thermodynamics Constrain Economic Processes? A Survey of Nicholas Georgescu-Roegen's Contribution to Ecological Economics, ***Ecological Economics,*** Vol. 22, pp. 203 - 223.
Surveys the introduction of thermodynamic concepts and methods into economic theory and modeling. Cited by 63.

Costanza, R. (1980). Embodied Energy and Economic Valuation. ***Science***, 210, 1219-1224.
The impact of energy on economic systems is examined. Cited by 190.

Dung, T.H. (1992). Consumption, Production, and Technological Progress: Unified Entropic Approach. ***Ecological Economics***, 6, 195-210.
This article reviews the application of the second law of thermodynamics to economic analyses. Cited by 9.

Faber, M. & Proops, J.L.R. (1985). Interdisciplinary Research Between Economists and Physical Scientists: Retrospect and Prospect. ***Kyklos***, 38, 599-616.
The benefits and drawbacks of cooperation between physical scientists and economists are explored. Cited by 18.

Georgescu-Roegen, N. (1971). The Entropy Law and the Economic Problem. ***University of Alabama Distinguished Lecture Series, 1***.
This article explains the impact of the laws of thermodynamics on the economic system. Cited by 130.

Georgescu-Roegen, N. (1975). Selections from "Energy and Economic Myths." ***Southern Economic Journal***, 41.
This article outlines some economic principles that are inconsistent with the laws of physics. Cited by 14.

Georgescu-Roegen, N. (1986). The Entropy Law and the Economic Process in Retrospect. ***Eastern Economic Journal,*** 12, 3-25.
This article discusses the second law of thermodynamics' application to the economy. Cited by 48.

Hannon, B. (1977). Energy, Labor, and the Conserver Society. ***Technology Review***, March/April 1977, 47-53.
The United States' energy options are explored. Cited by 4.

Hannon, B., M. Ruth, and A. Delucia. 1993. A Physical View of Sustainability, ***Ecological Economics***, Vol. 8, pp. 253 - 268.
Describes economic processes from a thermodynamic perspective. Cited by 15.

Judson, D.H. (1989). The Convergence of Neo-Ricardian and Embodied Energy Theories of Value and Price. ***Ecological Economics***, 1, 261-281.
The classical foundations of ecological economics, including energy theory and neo-Ricardian theory, are analyzed. Cited by 12.

Krutilla, J. (1967). Conservation Reconsidered. ***American Economic Review***, 57, 777-789.
This article questions whether technological progress can make up for the depletion of resources. Cited by 748.

Mirowski, P. (1988). Energy and Energetics in Economic Theory: A Review Essay. ***Journal of Economic Issues,*** XXII, 81-830.
This article explores the theory that energy is the origin of economic value. Cited by 19.

Odum, H. & Odum, E. (1976). Energy and Money. In H. Odum & E. Odum (Eds.) ***Energy Basis for Man and Nature*** (pp. 49-59). New York: McGraw-Hill.
This article examines the relationship between energy and money and their respective impacts on the economy. Cited by 218.

Peet, J. (1992). The Biophysical Systems World View. ***In Energy and the Ecological Economics of Sustainability***, (pp. 83-95). Washington, D.C. and Covelo, CA: Island Press.
This article compares the biophysical systems perspective and the political-economic perspective of economic analysis. Cited by 99.

Ruth, M. 1993. ***Integrating Economics, Ecology and Thermodynamics***, Kluwer Academic Publishers, Dortrecht, The Netherlands, 251 pp.
Presents the foundations of Ecological Economics, summarizes ongoing research and lays out future directions. Cited by 109.

Ruth, M. and C.W. Bullard. 1993. Information, Production, and Utility, ***Energy Policy***, Vol. 21, No. 10, pp. 1059 – 1066.
Presents methods to evaluate model and manage environmental impact of technology. Cited by 13.

Ruth, M. 1995. Information, Order and Knowledge in Economic and Ecological Systems: Implications for Material and Energy Use, ***Ecological Economics***, Vol. 13, pp. 9 - 114.
(This paper is also reprinted in R. Costanza, C. Perrings, and C.J. Cleveland (eds.) The Development of Ecological Economics, Edward Elgar, Cheltenham, Great Britain, pp. 360 - 375.)
Uses thermodynamic and information theory to describe the transformation of materials and energy in economic and ecosystems. Cited by 35.

Young, J.T. (1991). Is the Entropy Law Relevant to the Economics of Natural Resource Scarcity? ***Journal of Environmental Economics and Management***, 21, 169-179. The application of thermodynamics to economics is questioned. Cited by 42.

Throughput

Ausubel, J.H. (1992). Industrial Ecology: Reflections on a Colloquium. ***Proceedings of the National Academy of Sciences***, 89, 879-884.
This article defines industrial ecology and examines some of the issues of the field. Cited by 28.

El Serafy, S. & Lutz, E. (1989). ***Environmental and Resource Accounting: An Overview***. In Y.J. Ahmad, S. El Serafy, & E. Lutz (Eds.). ***Environmental Accounting for Sustainable Development***, (pp. 1-7). Washington, D.C.: The World Bank.
This article questions mainstream economists' treatment of industrial wastes as externalities, arguing that costs of ecosystem degradation should be internalized. Cited by 28.

Georgescu-Roegen, N. (1979). Energy Analysis and Economic Valuation. ***Southern Economic Journal***, 45, 1023-1058.
The idea that energy is the only source of value is examined, with the critique that "matter matters too." Cited by 80.

Graedel, T.E., Allenby, B.R., & Linhart, P.B. (1993). Implementing Industrial Ecology. ***IEEE Technology and Society Magazine***, 12, 18-26.
This article describes the application of ecology to industrial systems, including the use of waste products as inputs to minimize environmental impacts. Cited by 26.

Slesser, M. (1989). Toward an Exact Human Ecology. In P.J. Grubb & J.B. Whittaker (Eds.). ***Toward a More Exact Ecology*** (423-436). Oxford, England and Cambridge, MA: Blackwell Books.
This article explains the interrelated nature of the economy and the environment and explores a procedure called natural capital accounting, which uses embodied energy to calculate the economy's environmental impact. Cited by 2.

Valuing Environmental Goods and Services

Ackerman, F., & Gallagher, K. (2000). Getting the Prices Wrong: The Limites of Market-Based Environmental Policy. ***Global Development and Environment Institute Working Paper*** 00-05.
This article questions the efficacy of market-based environmental policy. Cited by 5.

Barbier, E.B. (1990). Alternative Approaches to Economic-Environmental Interactions. ***Ecological Economics***, 2, 7-26.
This article explores the economic valuation of environmental goods and services. Cited by 27.

Cleveland, C.J., Costanza, R., Hall, C.A.S., & Kaufman, R. (1984). Energy and the U.S. Economy: A Biophysical Perspective. ***Science***, 225, 890-897.
This article looks at the physical constraints on economic production. Cited by 186.

Cleveland, C.J. (1987). Biophysical Economics: Historical Perspective and Current Research Trends. ***Ecological Modeling***, 38, 47-73.
Biophysical economics, the idea that natural resources play a crucial role in human economies, is explored. Cited by 56.

Costanza, R. (1980). Embodied Energy and Economic Valuation. ***Science***, 210, 1219-1224.
The impact of energy on economic systems is examined. Cited by 190.

Costanza, R. & Daly, H.E. (1987) Toward an Ecological Economics. ***Ecological Modeling***, 38, 1-7.
This article argues that humanity's increasing impact on the environment requires a convergence of the disciplines of ecology and economics. Cited by 50.

Daly, H.E., & Townsend, K.N. (1993). ***Valuing the Earth: Economics, Ecology, Ethics***. Cambridge, MIT Press.
This explores the relationship of human beings, and economic activity, to the natural word. Cited by 104.

Heal, G. & Barbier, E. (2006). Valuing Ecosystem Services. ***Economist's Voice,*** January 2006.
This article explores the issues inherent in pricing environmental goods and services. Cited by 79.

Judson, D.H. (1989). The Convergence of Neo-Ricardian and Embodied Energy Theories of Value and Price. ***Ecological Economics***, 1, 261-281.
The classical foundations of ecological economics, including energy theory and neo-Ricardian theory, are analyzed. Cited by 12.

Mirowski, P. (1988). Energy and Energetics in Economic Theory: A Review Essay. ***Journal of Economic Issues***, XXII, 81-830.
This article explores the theory that energy is the origin of economic value. Cited by 19.

Odum, H. & Odum, E. (1976). ***Energy and Money***. In H. Odum & E. Odum (Eds.) Energy Basis for Man and Nature (pp. 49-59). New York: McGraw-Hill.
This article examines the relationship between energy and money and their respective impacts on the economy. Cited by 218.

Ruth, M. and C.W. Bullard. 1993. Information, Production, and Utility, ***Energy Policy***, Vol. 21, No. 10, pp. 1059 – 1066.
Presents methods to evaluate model and manage environmental impact of technology. Cited by 13.

Trainer, F.E. (1990). Environmental Significance of Development Theory. ***Ecological Economics***, 2, 277-286.
The impact of economic growth and ecological damage on global wellbeing is analyzed. Cited by 14.

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