The Unfinished Journey of Ecological Economics

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Abstract

The goal of the economists and ecologists who laid the conceptual foundations for ecological economics in the 1960s and 1970s was to create a scientifically informed discipline that could serve as the basis for coordinating economic activities in environmentally responsible ways. The aim of this article is to make a convincing case that the history of neoclassical economic theory provides a coherent basis for understanding why ecological economists must finish the journey begun by these economists and ecologists.

Introduction

The ideas of economists and practical philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed, the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influence, are usually the slaves of dead economists.

John Kenneth Galbraith

In textbooks on mainstream economic theory, virtually nothing is said about the ideas of the dead economists that rule the world and several studies have shown that the history of this theory has "all but vanished" in both undergraduate and graduate programs (Colander, 2007). A coded explanation of why this is the case is contained in two claims frequently made or clearly implied in the textbooks studied by students in these programs. The first is that the nineteenth century creators of neoclassical economic theory disclosed and described the previously hidden dynamics of free market systems and transformed the study of economics into a rigorously mathematical scientific discipline. The second is that extensions and refinements of this mathematical formalism by subsequent generations of mainstream economists fully disclosed and described these dynamics. The clear suggestion here is that the ideas of the dead economists who rule the world are irrelevant because the mechanisms of market systems are fully revealed in the mathematical formalism used by mainstream economists.

The economists and ecologists who laid the conceptual foundations for the disciple of ecological economics challenged the validity of assumptions about the dynamics of market systems in neoclassical economic theory in an effort to create an environmentally responsible economic theory (Martinez-Alier, 2002, O'Connor, 2000, Giampietro, 2001). Numerous attempts have been made to explain why ecological economics did not finish the journey begun by the founders of this discipline and is now listed in the *Journal of Economic Literature* under the heading “Environmental Economics.” The list of the usual suspects includes an overemphasis on methodological pluralism, a precarious and confused epistemology, a failure to properly define ontological assumptions, and a lack of scientific rigor (Spash, 2012, p. 37).

The aim of this discussion is to make a convincing case that the history of the ideas of the dead economists that rule the world provides a coherent basis for understanding why these problems exist and how they can be resolved. This history reveals that the mathematical formalism used by neoclassical economists is predicated on assumptions about economic reality that massively frustrate or effectively undermine efforts to implement scientifically viable and equitable economic solutions for environmental problems. Equally important for the purposes of this discussion, this history is replete with compelling reasons why ecological economics must become a radical discipline committed to completing the journey begun by its founders.

At this point, allow me to stress that the intent of this discussion is not to launch an ill-mannered attack on the intellectual or moral integrity of mainstream economists. If environmental sinks were inexhaustible, environmental resources unlimited, and the environmental impacts of economic activities relatively benign, the usefulness of neoclassical economic theory could be regarded as sufficient justification for its widespread application. However, this theory can no longer be viewed as useful in even strictly pragmatic or utilitarian terms because it fails to meet what must now be viewed as the fundamental criterion for the usefulness of any economic theory—the extent to which the theory can serve as the basis for coordinating economic activities in environmental responsible ways and preserve and protect the capacity of the biosphere to sustain the richness and diversity of life on planet Earth.

Origins of Neoclassical Economic Theory

There are no mentions in textbooks on neoclassical economic theory of a very salient and vitally important fact disclosed and described in great detail by Philip Morowski: Neoclassical economic theory was created by substituting economic constructs derived from classical economics for physical variables in the equations of a badly conceived and soon-to-be outmoded theory in mid-nineteenth century physics (Mirowski, 1988, 1999). The theory in mid-nineteenth century physics was developed from the 1840s to the 1860s in response to the inability of classical physics to account for the phenomena of heat, light and electricity. In 1847 Hermann-Ludwig Ferdinand von Helmholtz, one of the best known and most widely respected physicists at this time, posited the existence of a vague and ill-defined energy that could unify these phenomena. This served as a catalyst for a movement called “energetics” in which physicists attempted to explain very diverse physical phenomena in terms of a unified and protean field of amorphous energy that fills all space.

The theories developed by these physicists were not subject to proof in repeatable experiments under controlled conditions because they did not specify the actual character of the field of energy or provide a means of measuring and quantifying phenomena associated with this field. The amorphous character of energy in these theories obliged the physicists to appeal to the law of the conservation of energy which states that the sum of kinetic and potential energy is conserved. This appeal was necessary because it was the only means of asserting that the vaguely defined field of energy somehow remains the "same" as it undergoes changes and transformations.

The strategy used by the creators of neoclassical economics (Stanley Jevons, Leon Walras, Francis Ysidro Edgeworth, and Vilfredo Pareto) was remarkably simple-- they wrote down the equations from the theory in physics that finally emerged in the energetics movement and substituted economic variables for the physical variables. Utility was substituted for energy, the sum of utility for potential energy, and expenditure for kinetic energy. The forces associated with utility-energy were represented as prices and spatial coordinates described quantities of goods (Mirowski, 1988, p. 310).

The economists claimed that market systems are closed because the physical system described in the equations borrowed from the theory in physics was closed. Physicists in the mid-nineteenth century used the term "closed system" to describe a system in which no outside forces enter and nothing can change the internal dynamics that result in observable behavior or properties. These physicists also assumed that these dynamics will inexorably move closed systems toward states of equilibrium where energy is distributed in the most statistically probable way and change tends not occur because forces, influences and reactions cancel each other out.

Based on this nineteenth century scientific understanding of closed physical systems, the economists made the following claims about market systems: 1) market systems are closed and exist in a domain of reality separate and distinct from the external environment; 2) a field of utility-energy operates within closed market systems and forces associated with this field manifest as the dynamics of these systems; 3) these dynamics govern decisions made by economic actors and sustain closed market systems in states of equilibrium if they are not interfered with by external or exogenous agencies like government.

The economists claimed that the sum of utility is conserved because the sum of energy in the equations borrowed from the theory in physics was conserved. In the formalism that resulted from the substitution of economic variables for physical variables, forces associated with the field of utility-energy govern decisions made by economic actors and determine the real value or right price of goods and commodities. The prices paid by the actors generate capital which circulates in this field as an abstract embodiment of value in a closed loop from production to consumption with no inlets or outlets.

Since the sum of utility in the "immaterial" field of utility-energy is conserved, the economists claimed that production is a physical neutral process that does not alter the sum of utility. In an effort to justify this idea, they appealed to a very strange interpretation of the law of the conservation of matter, or the idea that matter cannot be created or destroyed. If matter, said the economists, is immutable, the production of goods and commodities cannot alter or change the basic stuff out of which they are made. They then argued that the immutable stuff out of which goods or commodities are made cannot be changed by production and any value associated with consumption must reside in the minds of economic actors (Morowski, 1989, pp. 290-291, 399).

Walras and Jevons included an additive utility function which signified that the utility of a good is solely the function of the quantity of the good consumed. The problem that these economists were attempting to resolve is that utility in the differential calculus borrowed from the theory in physics becomes progressively smaller. In an effort to explain why this is the case, the economists claimed that the utility experienced by an economic actor in the consumption of increasing larger amounts of a particular good gradually diminishes (Walras (1874) 1960; Jevons, (1871), 1970).

What is important to realize here is that the economists made these claims not because they had anything to do with the actual character of economic reality. They were obliged to make them in an effort to justify the idea that the mathematical formalism borrowed from the theory in physics disclosed and described the previously hidden dynamics of market systems. This formalism also obliged the economists to assume that forces associated with these dynamics act casually and deterministically on atomized economic actors to sustain market systems in states of equilibrium. In an effort to justify this assumption, the economists claimed that economic actors are supremely rational human beings with prodigious knowledge of all the complex variables involved in maximizing their utility.

This view of economic actors is not as strange as it may seem when one carefully examines the mathematical formalism borrowed from the theory in physics. In this formalism, the prodigious knowledge of the actors during the process of making economic decisions that maximize their utility is embedded in and a property of the field of utility-energy in which these decisions are made. This clearly implies that these decisions are solely determined by forces associated with the dynamics of closed market systems in the field of utility-energy.

This is not, as some might suppose, an esoteric intellectual problem with no real world consequences for the following reasons: It explains why there is no basis in the mathematical formalism used by mainstream economists for even recognizing, much less dealing with, the fact that economic decisions in the real world are often informed by and even predicated on moral values, ethical standards, and concerns about equity and fairness. It explains why mainstream economists have routinely dismissed or ignored the work of ecological economists who appeal to concerns about equity and fairness to justify the implementation of economic programs and public policies. And it also explains why the claim that the rigorously mathematical theories used by mainstream economists are value-free is bogus and only servers to disguise the fact that these theories sanction and perpetuate economic inequality, mitigate against equitable distribution of scarce environmental resources, and enhance the wealth, power and influence of financial elites (Pikkety, 2014).

A number of well-known mathematicians and physicists told the creators of neoclassical economic theory that the economic constructs were utterly different from the physical variables and that it was not possible to assume that the constructs were in any sense comparable to the variables (Mirowski, 1988, pp. 11-43; Ingrao and Israel, 1990, pp. 139-173). However, the economists refused or, more probably, failed to comprehend, how devastating this criticism was and proceeded to claim that they had transformed the study of economics into a rigorously mathematical scientific discipline like physics.

As it turned out, the origins of neoclassical economic theory in mid-nineteenth physics were forgotten, subsequent generations of mainstream economists disguised the axiomatic assumptions about the dynamics of market systems under an increasingly more elaborate maze of mathematical formalism, and the claim that the theory is scientific was almost universally accepted (Nadeau, 2003, 2008). Meanwhile, the mid-nineteenth theory in physics was largely forgotten after James Clerk Maxwell published a theory of electromagnetism that provided a coherent scientific basis for understanding the phenomena of heat, light, electricity and magnetism (Maxwell, *A Dynamical Theory of the Electromagnetic Field, 1865*).

The Rationality of Irrationality

In order to appreciate how the creators of neoclassical economic theory tried to justify the claim that utility could be substituted for energy in the equations borrowed from the theory in physics, consider the following passages from William Stanley Jevons's major work, *The Principles of Science*: "Life seems to be nothing but a special form of energy which is manifested in heat and electricity and mechanical force. The time may come, it almost seems, when the tender mechanism of the brain will be traced out, and every thought reduced to the expenditure of a determinate weight of nitrogen and phosphorous. No apparent limit exists to the success of the scientific method in weighing and measuring, and reducing beneath the sway of law, the phenomena of matter and mind…Must not the same inexorable reign of law which is apparent in the motions of brute matter be extended to the human heart?" (Jevons, (1874), 1905, pp. 735-736).

Mind, says Jevons, is a manifestation of energy, the physical substrate of mind can be reduced to a measurable quantity, such as the "weight of nitrogen and phosphorous," and the "phenomena" of mind are potentially explainable in terms of collections of particles subject to the "inexorable reign" of deterministic physical laws. If one actually believed, as Jevons apparently did, that this is the case, it would not require a great leap of faith to arrive at the conclusion that the collection of particles in the mind of an economic actor is subject to the deterministic forces that operate within the protean field of utility-energy described in the equations of his mathematical theory.

In the following passages from *Theory of Political Economy*, Jevons defends the claim that his theory is scientific: "It is clear that Economics, if it is to be a science at all, must be a mathematical science. There exists much prejudice against attempts to introduce the methods and language of mathematics into any branch of the moral sciences….. My theory of Economics is purely mathematical in character….The theory consists of applying differential calculus to the familiar notions of wealth, utility, value, demand, supply, capital, interest, labour, and all the other quantitative notions belonging to the daily operations of industry….To me it seems that our science must be mathematical, simply because it deals in quantities. Whenever things treated are capable of being greater or less, there the laws and relations must be mathematical in nature" (Jevons, (1871), 1970, pp. 18-19).

Jevons claims that his theory is scientific because it describes the behavior of economic actors in terms of well-defined quantities with the use of the differential calculus. The large problem here is not merely that Jevons fails to realize that decisions made by economic actors cannot be described in these terms. It is also that the theory in physics that contained the equations which served as a template for his mathematical formalism was very different from theories in classical physics.

In classical physics, one universal force, gravity, governs the interactions of mass points or particles and these interactions are described in terms of vectors such as momentum. However, physical interactions in the theory in physics that emerged during the energetics movement are presumed to be emergent from a vaguely defined field of protean energy and these interactions are described in terms of scalars in this field (Mirowski, 1998, p. 17). Also, one does not have to be a trained logician to appreciate the absurdity of Jevon's circular argument-- the theory must be scientific because it is mathematical and the theory must be mathematical because it is scientific (Nadeau, 2006, 2008).

Walras viewed nineteenth century physics as the unequaled model of scientific knowledge and his grand ambition was to use this model to create "the science of economic forces, analogous to the science of astronomical forces" (Walras, "Letter to Louis Ruchonnet," 1874). In *Elements of Pure Economics*, Walras claims that the forces that operate in the field of utility/energy described in his mathematical theory are comparable to the force of gravity and govern the interactions of economic actors in much the same way that gravity governs the interactions of masses of objects. He then says that these forces inexorably move competitive prices toward a state of equilibrium in much the same way that the force of gravity inexorably moves physical systems toward this state (Walras, (1874), 1960, p. 40). Subsequent generations of mainstream economists appealed to this analogy to justify the claim that neoclassical economic theory is derived from classical physics and predicated on scientifically valid assumptions about physical reality in this physics. What these economists apparently failed to realize is that this analogy applies to classical physics and not to the theory in mid-nineteenth century physics that contained the equations Walras used to create his allegedly scientific economic theory.

Francis Ysidro Edgeworth and Vilfredo Pareto were also convinced, like Jevons and Walras, that they had transformed the study of economics into a rigorously mathematical scientific discipline. The enthusiasm with which Edgeworth preached this gospel is apparent in the following passages: "The application of mathematics to the world of the soul is countenanced by the hypothesis (agreeable to the general hypothesis that every psychical phenomena is the concomitant, and in some the sense the other side of a physical phenomenon), the particular hypothesis, adopted in these pages, that Pleasure is the concomitant of Energy. Energy may be regarded as the central idea of Mathematical Physics: maximum energy the object of the principle investigations in that science…As the movements of each particle, constrained or loose, in a material cosmos are continually subjugated to one maximum sub-total of accumulated energy, so the movements of each soul whether selfishly isolated or linked sympathetically, may continually be realizing the maximum of pleasure" (Edgeworth, 1881, pp. 9, 12).

Pareto's position, although more pugnacious, is essentially the same as that of Edgeworth: "Strange disputes about predestination, about the efficacy of grace, etc., and in our own day incoherent ramblings on solidarity show that men have not freed themselves from these daydreams which have been gotten rid of in the physical sciences, but which still burden the social sciences…Thanks to the use of mathematics, this entire theory, as we develop it in the Appendix, rests on no more than a fact of experience, that is, on the determination of the quantities of goods which constitute combinations between which the individual is indifferent. The theory of economic science thus acquires the rigor of rational mechanics" (Pareto, (1906), 1971, pp, 36, 113).

A Green Thumb on the Invisible Hand

Ecological economists are very much aware that the claim that the creators of neoclassical economics transformed the study of economics into a rigorously mathematical discipline is bogus. However, the problem here is not the claim that neoclassical economic theory is clothed in the raiment of scientific knowledge. The problem is that assumptions about the dynamics of market systems in the mathematical formalism now used by mainstream economists tend, almost invariable, to undermine the prospect of implementing scientifically viable and equitable economic solutions for environmental problems. This problem is particularly obvious in the work done by mainstream economists in the sub-discipline of environmental economics.

Environmental economists presume that the health of national economies is sensitively dependent on the consumption of increasing larger amounts of natural resources because neoclassical economic theory is predicated on the assumption that GNP and GDP in functional market systems must expand. They also presume that the value of natural resources can only be fully disclosed by the prices that economic actors have paid for these resources because the real value or right price in neoclassical economic theory is determined by forces that operate within closed market systems and legislate over decisions made by these actors. When these economists calculate the environmental costs of economic activities, they assume that the relative price of "each bundle" of an environmental good, service, or amenity reveals the "real marginal values" of the consumer.

Note how the writers of a standard textbook on environmental economics attempt to justify these assumptions: "The power of a perfectly functioning market rests in its decentralized process of decision making and exchange; no omnipotent planner is needed to allocate resources. Rather, prices ration resources to those that value them the most and, in doing so, individuals are swept along by Adam Smith's invisible hand to achieve what is best for society as a collective. Optimal private decisions based on mutually advantageous exchange lead to optimal social outcomes" (Hanley, Shrogren, and White, 1997, p. 358).

In environmental economics, the belief that optimal private decisions "based on mutually advantageous exchange lead to optimal social outcomes" for the state of the environment is a primary article of faith. Environmental economists qualify this belief by stipulating that these optimal social outcomes will not occur unless the following conditions apply: the market systems in which economic actors make private decisions operate more or less perfectly; and the prices, or values, of environmental goods and services are represented as a function of these decisions. However, if these conditions are met, environmental economists assume that forces associated with the dynamics of market systems will "lead to optimal social outcomes" for the state of the environment when the "prices are right."

The right price in environmental economics is the price that economic actors have paid, or might be willing to pay, to realize some marginal benefits of consuming or preserving environmental goods and services. Environmental resources that cannot be valued in these terms are viewed as "externalities" because neoclassical economic theory is predicted on the assumption that the right price of these resources can only be determined by forces that operate within closed market systems. Mainstream economists use the term externalities to describe situations in which the production or consumption of one economic actor affects another who did not pay for the good produced or consumed. However, when environmental economists use the phrase "environmental externalities," they are also referring to environmental goods and services whose real value or right price cannot be determined by forces that operate within closed market systems and govern decisions made economic actors.

Environmental economists often use cost-benefit analyzes different from those used by other mainstream economists to place a value on environmental externalities. The problem that these accounting procedures are intended to resolve is that the "real" marginal values of environmental resources can only be determined by prices economic actors have paid for these resources. Given that the vast majority of natural resources in the global environment cannot be valued in these terms, environmental economists have developed indirect methods designed to estimate the "use-value" of these resources.

For example, environmental economists use "contingent valuation surveys" to assess the use value of non-market resources such as recreation, scenic beauty, air quality, water quality, species preservation, and bequests to future generations. The word "contingent" is meant to highlight the fact that the values disclosed with the use of these surveys are contingent on the artificial or simulated market conditions described in the surveys. The intent of these surveys is to determine the amount that economic actors might be willing to pay to preserve natural environments (preservation or existence values), maintain the option of using natural resources (option values), and bequeath natural resources to future generations (bequest values). This is normally accomplished by asking the respondents to indicate the maximal amount they are willing to pay for an increase in the quality of an environmental resource and the minimal amount they are willing to accept as compensation to forgo this increase.

The vitally important but rarely asked question here is how could environmental economists possibly assume that the amount of money that people with a wide range of educational levels and average incomes might be willing to pay to preserve an environmental resource or resolve an environmental problem can serve as the basis for implementing public policies that have optimal social outcomes? They do by appealing covertly or overtly to two axiomatic assumptions embedded in the mathematical formalism used by these economists. The first is that market systems are closed and the value of environmental resources can only be determined by forces that operate within these systems. The second is that these forces manifest as the lawful or law-like dynamics of market systems that govern decisions made by economic actors and determine the true value or right price of these resources (Nadeau, 2013).

Cracks in the Foundations of Neoclassical Economic Theory

A fair number of mainstream economists, including luminaries like Arrow and Hahn, have expressed grave doubts about the efficacy of neoclassical economic theory (Arrow and Hahn, 1999). As R. Sugden puts it: “There was a time, not long ago, when the foundations of rational-choice theory appeared firm, and when the job of the economic theorist seemed to be one of drawing out the often complex implications of a fairly simple and uncontroversial system of axioms. But it is increasingly becoming clear that these foundations are less secure than we thought, and that they need to be examined and perhaps rebuilt. Economic theorists may have to become as much philosophers as mathematicians” (Sudgen, 1991, p. 783).

Wassily Leontief, a Nobel Laureate in economics, also expressed doubts about the efficacy of the orthodox neoclassical paradigm: “Page after page of professional journals are filled with mathematical formulas leading the reader from sets of more or less plausible but entirely arbitrary assumptions to precisely stated but irrelevant conclusions….Year after year economic theorists continue to produce scores of mathematical models to explore in great detail their formal properties; and the econometrics fit algebraic functions of all possible shapes to essentially the same sets of data without being able to advance, in any perceptible way, a systematic understanding of the structure and the operations of a real economic system” (Leontief, 1981, pp. 104-107).

But as ecological economists know all too well, this does not mean that mainstream economists are in the process of developing a new economic paradigm. Virtually all of the most advanced theoretical work in mainstream economics is premised on the assumptions that market systems are, by varying degrees, closed, self-correcting, and self-sustaining. And the primary impulse in most of this theoretical work is to disclose the hidden dynamics that move market systems toward optimal states of equilibria with the use of increasingly more sophisticated mathematical techniques.

For example, nonlinear analysis, particularly convex analysis, has been used to buttress the claim of the game theorists that mathematical models of conflict and resolution between intelligent decision makers can disclose the hidden dynamics or immaterial logics of market systems. The mathematical formalism used in nonlinear analysis, as the work of Jeanne-Pierre Aubin illustrates, is staggeringly complex. But as the title of Aubin’s best-known book attests, *Optima and Equilibria: An Introduction to Nonlinear Analysis*, the ghost in the machine is the forces that allegedly sustain market systems in states of equilibrium and the intent in this densely mathematical treatise is to uncover the hidden dynamics or immaterial logics that are allegedly a manifestation of these forces (Aubin, 1998).

Behavioral economists have challenged and effectively undermined the myth that economic actors are supremely rational human beings with a prodigious amount of knowledge of all the complex variables involve in making economic decisions. However, the primary aim of these economists is to assist economic actors in the process of maximizing their utility by learning to distinguish between economic decisions driven by intuitive or emotional cognitive processes and those informed by more deliberative and logical cognitive processes. While this view of Homo economicus is vastly more sophisticated in psychological terms than that in neoclassical economic theory, all of the other assumptions about the dynamics of market systems in the work of the behavioral economists are the same as those in this theory.

Another related problem is that the vast majority of mainstream economists who work in business and government are not terribly concerned with the most advanced theoretical work in their discipline. Legions of these economists are engaged on a daily basis in developing analyses and making predictions that guide the decision-making of political leaders and economic planners and that serve to legitimate assumptions about economic reality in the neoclassical economic paradigm. Many of these economists are aware of the negative impacts of economic activities and seek to minimize them as long as profit margins can be maintained. These good intentions are, however, typically defeated by our now familiar culprit— assumptions about economic reality in neoclassical economic theory that make it virtually impossible to resolve environmental problems in economic terms.

Mainstream economists will readily admit that the supremely rational actor depicted in their mathematical theories does not exist. But as *New York Times* columnist David Brooks points out, they also "argue this caricature is close enough to reality to build models that accurately predict real human behavior. Moreover, the caricature allows them to build rigorous mathematical models, which are the measure of true genius in the economics profession. It allows them to turn economics from a soft squishy muddleheaded field like psychology into a hard, rigorous, and tough minded field like physics" (Brooks, 2011, p. 178).

Ecological Economics

The ecologists and economists who laid the conceptual foundations for the emerging discipline of ecological economics were inspired by and benefited from earlier work done by two economists, Ciriacy-Wantrup and Kapp, who challenged the validity of assumptions about the dynamics of market systems in neoclassical economic theory (Spash, 1999). Ciriacy-Wantrup advocated a safe minimal standard for the environmental impacts of economic activities, criticized the use of cost-benefit analysis to assess these impacts, and stressed the importance of uncertainty in making these assessments (Ciriacy-Wantrup, 1952). Kapp argued that the environmental problems that mainstream economists view as “externalities” should be viewed as social costs resulting from the structure and incentives in free market capitalism. He also made the case that vested interests distort the prices paid for environmental resources in ways that do not reflect the scarcity of these resources (Kapp, 1961).

During the late 1960s and early 1970s, efforts were made to transform ecological economics into a more scientifically informed discipline by appealing to the first and second laws of thermodynamics. Ecologist Howard Odum used these laws to develop a mathematical model which showed that capital flows are linked to energy flows that have environmental impacts. After demonstrating that low-entropy inputs enter real economic processes and become high-entropy outputs and wastes, Odum concluded that the assumption in neoclassical economic theory that market systems are closed makes no sense at all in scientific or ecological terms (Odum, 1973).

Another seminal figure in the emerging discipline of ecological economics, Georgescu-Roegen, made a convincing case that the mathematical analysis of production in neoclassical economic theory is fundamentally flawed because it fails to incorporate the laws of thermodynamics. In his view, an economy must be viewed as a unidirectional flow in which inputs of low-entropy matter and energy are used to produce two kinds of outputs—goods and services and high entropy waste and degraded matter (Georgescu-Roegen, 1971).

During the decades that followed, ecological economics became increasingly more interdisciplinary and fragmented into a variety of different, often contradictory approaches (Ropke, 2005, Turner, 1997, Spash, 1999, van den Bergh, 2001, Costanza, 2002, Soderbaum, 2000, Martinez-Alier, 2002). Some ecological economists attempted to demonstrate that the methods used by mainstream economists to determine market prices for environmental resources are not valid in epistemological terms and fail to take into account demographic, social and cultural variables. Others attempted to redefine the discipline as a science of social change committed to developing institutional frameworks that feature sustainable production and consumptions patterns (Ropke, 2005, Spash 1997, 2012).

However, as Spash points out, the dominant trend in ecological economics in the United States over the last two decades has been “to link standard and ecological models” and produce “research which would fit comfortably within neoclassical environmental economics” (Spash, 1999, p. 415). The mistake, if one can call it that, made by the ecological economists who did this research is the presumption that mainstream economists would be willing to revise or modify axiomatic assumptions in their mathematical theories in an effort to implement scientifically viable economic solutions for environmental problems. Given the enormous extent to which these assumptions have contributed to the environmental crisis and are frustrating its resolution, there is obviously nothing unreasonable about this presumption. However, the fact that there has been very little meaningful dialogue between ecological economists and mainstream economists clearly suggests that the former are saying something that the latter does not wish to hear.

The Clothes of the Emperor

Perhaps the best way to try to explain why this is the case is to consider the work done by Herman Daly. In *Steady State Economics*, Daly claims that there is no basis in neoclassical economic theory for accounting for the throughput of low-entropy natural resources and that the emphasis on money flows creates the illusion that perpetual economic growth is always possible and desirable (Daly, 1993). The solution to these problems, says Daly, is to use constraints associated with the second law of thermodynamics to formulate policies for long-term sustainability, such as taxes on energy and virgin resources. In his view, these policies would increase social awareness of ecological limits and promote the realization that "physical flows of production and consumption must be minimized subject to some desirable population and standard of living" (Daly, 1993, p. 186).

According to Daly, the three basic goals of an economic system should be efficient allocation, equitable distribution, and sustainable scale. The first goal in his view is implicit in neoclassical economic theory and the second can be accomplished by implementing public policies within the framework of this theory. However, he also argued that there is nothing in this theory that can account for scale and no policy instruments that deal with scale. Daly defines scale as the total physical volume of low-entropy raw materials that move through the open subsystem of an economy and back into the finite and non-growing global environment as high-entropy wastes (Daly, 1992, p. 186).

Based on the scientifically valid assumption that the scale of the global economy has grown dangerously large relative to the ecosystem, Daly concluded that this economy is sustainable only if it does not erode the carrying capacity of this system. The large problem here, said Daly, is that there is no basis in neoclassical economic theory for even recognizing the existence of this scientific truth. One reason why this is the case is the assumption in this theory that the value of natural resources can only be determined by the prices that economic actors have paid or might be willing to pay to consume or preserve these resources.

According to Daly, this not only explains why mainstream economists have failed to recognize that distribution and scale "involve relationships with the poor, the future, and other species that are fundamentally social in nature rather than individual." It also explains why decisions involving these relationships exist on the same plane as the choice between chewing gum and a candy bar and why ethical concerns about these relationships are reduced to the level of "personal tastes weighted by income" (Daly, 1992, pp. 190-191).

In spite of the fact that Daly privileges market mechanisms and embraces some of the assumptions about the dynamics of market systems in neoclassical economic theory, his work has been roundly criticized and routinely dismissed by mainstream economists. In my view, there are two major reasons why the work of Daly has not been warmly received by these economists. The first is that Daly challenged the validity of the assumption in neoclassical economic theory that market systems can perpetually grow and expand. The second is that his scientifically valid claim that economic activities are embedded in and interactive with environmental systems challenged the validity of the assumption that market systems are closed.

If mainstream economists admitted that this is the case, they would be obliged to recognize that the dynamics of closed market systems purportedly disclosed and described in their mathematical formalism do not exist. They could no longer claim that these dynamics govern decisions made by economic actors, promote the growth and expansion of market systems, and sustain these systems in states of relative equilibrium. Mainstream economists in the sub-discipline of environmental economists could no longer claim that the only basis for assessing the real value or right price of environmental resources is the amount of money economic actors are willing to pay to consume or preserve these resources. These economists would also be obliged to admit that there is absolutely no basis for assuming that “private decisions based on mutually advantageous exchange lead to optimal social outcomes” for the state of the environment.

Also consider the role played by mainstream economists in the process of developing the scenarios for mitigating the impacts of climate change that will soon be considered by the diplomats involved in the effort to implement a post Kyoto agreement. During this process, mainstream economists use computer based integrated assessment models with hundreds of input parameters to analyze the economic impacts of climate change. The little known but very large problem here is that these models are programmed to assess the economic impacts of climate change based on axiomatic assumptions about dynamics of market system in the mathematical formalism used by mainstream economists.

This explains why all of the mitigation scenarios in the Fifth Assessment Report are predicated on the assumption that these dynamics will sustain market systems in states of equilibrium and promote their growth and expansion from now until the year 2100. It also explains why all of these scenarios feature discount rates and presume that the growth and expansion of the global market system will generate most of the capital needed to cover the mitigation costs. More important for the purposes of this discussion, none of these mitigation scenarios would reduce worldwide emissions of greenhouse gases to the levels required to prevent the worst consequences of climate change (Pindyck, 2009; Rosen and Guenther, 2014).

Another related problem is that the integrated assessment models programmed to assess the economic impacts of climate change are based on the assumption that the value of natural resources can only be determined by forces that operate within closed market systems and govern decisions made by actors. This explains why nothing is said in the mitigation scenarios in the Fifth Annual Report about the economic impacts of climate change on environmental systems and processes that have no economic value in the mathematical formalism used by mainstream economists. Equally problematic, no attempt was made in these mitigation scenarios to assess the potential impacts of increases in the intensity and frequency of extreme weather events on the already fragile and prone to collapse global financial system (Barnowski, 2012; Korowicz, 2013). The reason why that this is the case is that there is no basis in the macro-economic modules used by mainstream economists for making these assessments (Rosen and Guenther, 2014).

The Unfinished Journey of Ecological Economics

It seems clear, as Spash puts it, that ecological economics "as a conservative enterprise is an unnecessary waste of time, merely shadowing environmental and resource economics. Ecological economics as a radical movement is required today, more than ever, in order to change the social organizations and institutions that spread false beliefs about economic, social and environmental reality" (Spash, 2012, p. 46). It also seems clear that the radical movement in ecological economists needed today must complete the journey begun by the economists and ecologists who laid the conceptual foundations for this discipline.

These economists and ecologists realized that assumptions about the dynamics of market systems in neoclassical economic theory preclude the prospect of implementing the scientifically viable and equitable economic programs and public policies needed to effectively deal with the environmental crisis. They also realized that the process of implementing these programs and policies would require massive changes in the "social organizations and institutions that spread false beliefs about economic, social and environmental reality" (Spash, 2012, p. 46). Equally important, these economists and ecologists were very much aware that scientifically valid assumptions about the relationship between economic activities and environmental systems are categorically different from and completely incompatible with assumptions about this relationship in neoclassical economics theory.

One reason why ecological economics failed to complete the journey begun by the founders of this discipline, as Soderbaum puts it, is that mainstream economists "tend to use their power positions to build cartels and to discriminate against all kinds of economists who represent a threat to orthodoxy" and seem to be "more eager to save their theories and methods than to improve the chances of human survival on this planet" (Soderbaum 1990, pp. 482, 491). If ecological economists are committed to improving the chances for human survival, they must be prepared and willing to openly and very publicly challenge the validity of false beliefs about economic reality in the theories and methods used by mainstream economists. It also seems clear that if this does not happen, the radical movement in ecological economics needed today will not emerge.

As the previous discussion attests, many ecological economists have challenged the validity of some of the false beliefs about economic reality in neoclassical economic theory. However, virtually all of these ecological economists are attempting, as Spash put it, "to link standard and ecological models" and produce research which would fit comfortably within neoclassical environmental economics" (Spash, 1991, p. 415). The problem here is not merely that the work of these ecological economists has been largely dismissed or ignored by mainstream economists for the same reasons that these economists have dismissed or ignored the work of Herman Daily. It is also that research that is compatible with neoclassical environmental economics must be predicated in part on unscientific assumptions about the dynamics of market systems that massively frustrate or greatly compromise efforts to implement scientifically viable and equitable economic solutions for environmental problems.

The ecological economists in the radical movement in this discipline needed today would not, like mainstream economists, dismiss or ignore the scientific truth that economic activities and environmental systems as embedded in and interactive with the nonlinear system of the biosphere on the local, regional and global levels. They would not assume, like mainstream economists, that the enormous diversity of human life can be reduced to the linear, quantitative measures of GDP and GNP and represented in terms of monetary coefficients (Kubiszewski et al, 2013, Costanza et al., 2014). Unlike mainstream economists, these ecological economists would also have a robust scientific understanding of the nonlinear interactions between human and environmental systems and the biophysical limits of economic growth (Rees, 1992, 2011; Rockstrom et al., 2009; Wackernagel et al., 2002; Constanza et al., 2012). And they would use this understanding to develop the scientifically and equitable economic programs and public policies needed to mitigate the impacts of climate change and resolve other menacing environmental problems.

During the process of developing these programs and policies, a clear distinction would be made between bad and good economic growth. Bad economic growth in the view of these ecological economists would be production processes and services that consume fossil fuels, deplete natural resources, degrade ecosystems, and externalize social and environmental costs. Good economic growth would be production processes and services that rely on renewable sources of energy, produce zero emissions, recycle natural resources, protect and restore ecosystems, and fully internalize social and environmental costs. These ecological economists would also realize that good economic growth has social and cultural dimensions that can only be measured in qualitative terms and that must be taken into account in an effort to deal with environmental problems in economic terms.

The ecological economists in this radical movement would not only be prepared and willing to publicly challenge the claim that neoclassical economic theory is value free and to explain in non-technical language why assumptions about economic reality in this theory are a program for ecological disaster. They would also be prepared and willing to make a very convincing case that neoclassical economy theory must be replaced by an environmentally responsible value laden economic theory. This theory would be scientific in the sense that it would provide a coherent basis for implementing scientifically viable economic solutions for environmental problems. And it would be value laden in the sense that economic growth would be measured in terms of increases in the health and happiness of people, households and communities and the extent to which this growth enhances the flourishing of life on Earth and the wellbeing of all of its human inhabitants (Korten, 2011).

The practitioners of this radical discipline will be repeatedly told by self-proclaimed realists and pragmatists in business and government that their understanding of what will be required to “improve the chances of human survival on this planet” is a product of the overheated imaginations of muddle-headed idealists who fail to recognize or properly understand what they regard as self-evident truths--the more invidious aspects of human nature, the harsh realities of geopolitical politics, the intimate connection between economic prosperity and competitive advantage, the vital importance of protecting and enhancing the interests of sovereign nation-states, and so on.

The problem with this conventional wisdom is that the usual distinctions between idealism and realism, moral actions and pragmatic solutions, and idealistic conceptions of the better world that could be versus rational assessments of the world as it is are no longer commensurate with the terms of human survival. What these terms dictate that is that idealism must be the new realism, moral actions are the only means of achieving pragmatic solutions, and idealistic conceptions of the better world are the only rational basis for preserving and protecting the biological diversity and natural resources that sustain human life.

Some ecological economists will be understandably reluctant for both professional and personal reasons to respond to this call to take up intellectual arms and participate in the process of creating the radical movement in this discipline desperately needed today. One source of this reluctance, as Ropke puts it, is that "a general critique of neoclassical economic theory is sometimes seen as outright counterproductive, because it tends to isolate ecological economics as a marginalized sect and to scare away both the influential economists and the large number of potential members who could fill the ranks of society" (Ropke, 2005, p. 281).

However, this resistance could be overcome if ecological economists realized that they now have a once in all human lifetimes opportunity. The opportunity is to protect the lives of the 7.3 billion members of the extended human family and to enhance the prospects that subsequent generations of this family will be able to live their lives on a flourishing Earth. This is not merely the work of an age but a work that can preserve the memory of all ages, and it is hard to imagine that anyone could serve a greater good or answer to a higher calling.

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