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The creationist foundations of Herman Daly's steady state economy

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Introduction

The notion of a steady state economy (SSE) has been central to the sustainability debate since the 1970s (Daly, 1973, 1977). Especially in North America, ecological economics has been strongly identified with the SSE. Its best-known advocate, Herman Daly, used the concept to make eloquent critiques of economic growth that helped build the foundations of ecological economics. He was a tireless popularizer of the adverse effects of economic growth on human well-being and the natural world. We argue that Daly's formulation of the SSE cannot be fully understood without examining its creationist core.[1] In numerous articles, including one published posthumously in this Journal (Daly, 2022), he makes false claims about well-established facts of evolution and evolutionary theory. His opinions are not backed by any credible evidence or references to the relevant scientific literature. Daly rejects the basic understandings of contemporary evolutionary biology and its naturalistic (non-supernatural) explanation for the origin of life and the place of humans in the biosphere. For Daly, accepting neoDarwinian[2] evolution is tantamount to accepting the extreme view that the world around us is strictly predetermined, with no place for human agency or purpose. This idea is the starting point for his formulation of the SSE. He maintains that the way out of this impasse is to reject neoDarwinian materialism and to embrace a system of value that will provide a way to objectively evaluate different states of the world and guide policy. In Daly's view, objective value is given by Judeo-Christian religion and this system of value will lead to the steady state. Each component of Daly's framework is problematic as is the logic linking them. Daly has espoused these views for decades in numerous publications (Daly, 1977, 1995, 1999, 2002, 2013b, 2019, 2022).

Although he does not use the term, Daly advocates "intelligent design" as an alternative to evolutionary biology. He maintains that life could not have originated from non-life without divine intervention and, likewise, the human mind (consciousness, intellect, souls) cannot be explained by science and must also be the result of divine intervention. Daly uses these claims to attack "materialist naturalism" as a

[1] This paper grew out of a lively exchange between Daly and Gowdy in the Spring of 2022 concerning an earlier version of Daly's (2022) RWER paper. See Gowdy comment (2022).

[2] Following Daly, we use the term neoDarwinian to refer to contemporary evolutionary biology.

world view.[3] According to Daly, contemporary biology views evolution as a completely random, non-directional process that produces the characteristics of the biosphere by pure chance. He maintains that a belief in natural explanations for the world around us implies a determinism that precludes free will, choice, and purpose (Daly, 2002, 2013b, 2019, 2022). This leads him to further argue that evolutionary theory precludes its adherents from making ethical judgments (Daly, 1999, 2022).

Daly's faulty interpretation of evolutionary theory leads him to the conclusion that it is a "metaphysical world view" and a major obstacle to a sustainable society. "It seems that an ecologically sustainable economy, as a policy of creation care, will not get far in a world dominated by materialist naturalism" (Daly, 2019, 3).[4] Daly's steady state has been subject to criticism (Georgescu-Roegen, 1989; Klitgaard and Krall, 2011; Krall and Klitgaard, 2011; Pirgmaier, 2017; Smith, 2010) but the creationist foundations of his system of thought have not been widely recognized, if at all. For Daly "growthmania" is not primarily the fault of capitalism, greed, economic power or anything structural about the economy. It is the hubris of materialist evolutionary biology that prevents us from achieving a sustainable society.

> However, a society unable to enact and enforce serious policies because it is lured by the lurking fecklessness of neodarwinism, runs its own risk of suicide. The survival value of neodarwinism is likely negative for the society that adopts it as its worldview. (Daly, 2006b, 16)

This article is not about Daly's religion *per se.* It is about his faulty understanding of basic concepts from evolutionary biology and how this misunderstanding forms his rationale for the SSE. For him, failure to address the excesses of economic growth is a moral failure rooted in neoDarwinian evolutionary theory. Grounded in creationism, Daly's vision of the steady state is ahistorical, based on marginal analysis and comparative statics, and built on a rejection of modern evolutionary science. Ecological economics was founded on the promise of finding common ground between economics and ecology. Daly's rejection of basic biological science needs to be addressed. In the pages below we discuss the social/political context of Daly's creationism, the steps of Daly's argument from evolutionary theory to objective value, and the relevance of his creationism to his concept of the steady state.

Daly's Creationism in Context

To understand Daly's positions on evolutionary biology, it is important to understand the origin and the context of his opinions. Daly's creationism is part of a broader tradition, centered in the United States, intent on replacing modern evolutionary biology with a supernatural understanding of the origin of life and the place of humans in the modern world. The leading advocate for creationism and for the teaching of intelligent design in public schools is the Discovery Institute, founded by the conservative commentator George Gilder in 1990. The Discovery Institute uses a number of strategies to promote creationism and to generate controversies where none exist in the scientific community. Each of these are embraced by Daly.

[3] In various articles, Daly also refers to materialism and materialists as "scientism", "neodarwinists, naturalists", "high intelligentsia", "modern intelligentsia", "scientific materialists", "mechanistic biologists", "monists", "scientists" or "biologists."

[4] Although creationism is encountered most frequently in North America, the movement is making headway in Europe (Blanke and Kjaergaard, 2016).

1. The God of the gaps - Biologists cannot explain the origin of life or the "uniqueness" of humans so some supernatural agent must be responsible for both.

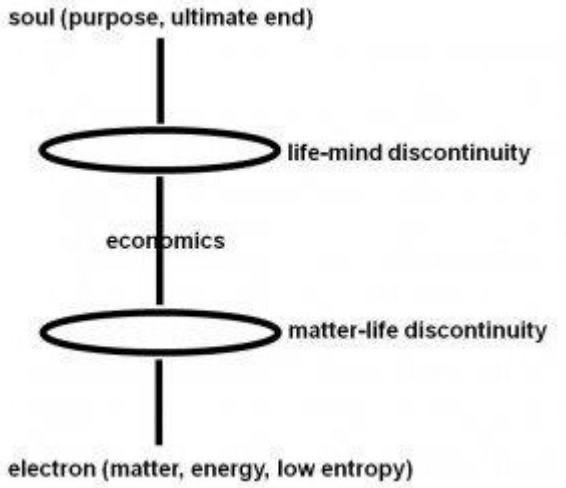
2. Irreducible complexity – Evolution cannot explain how life's complex features arose, so there must be a supernatural explanation.

3. Teach the controversy. There is great controversy among biologists about the validity of modern evolutionary science, so why not teach creationism as well.

The God of the gaps

Creationists claim that there are two gaps in the history of life on earth that can only be explained by divine intervention. God made two interventions as illustrated in Daly's (2013b, 2) representation of "dualist economics," which claims there is a discontinuity between the material universe, subject to the entropy law, and the human soul giving purpose to human agency.

Figure 1. Daly's Dualist Economics and Creationist Talking Points



The matter-life discontinuity requires a supernatural intervention to create life on earth. Science cannot explain the origin of life. Daly's characterization of how biologists view the emergence of life shows a lack of understanding of the modern literature in evolutionary biology. He writes:

> When confronted by other scientists with the extreme fine-tuning of the physical laws and numerous constants necessary for life, the materialists admit that the compound probability that life emerged in our universe by chance is infinitesimal. So, they postulate infinitely many (unobservable) universes in which the infinitesimal probability, multiplied by infinitely many trials, could, and evidently did, happen. (Daly, 2022, 12)

Who are the "materialists" who "admit" that the probability that life emerged by chance is infinitesimal and that it required an infinite number of universes? Daly ignores contemporary biology and the

extensive research on the origin of life.[5] According to Daly, materialists say that everything that exists is due to pure chance. Daly maintains that biologists believe that for life to appear there must be an infinite number of universes with an infinite number of random chances. His only source for this assertion, given in numerous publications (Daly, 2006a, 2013b, 2015a), is an offhand remark by Francis Crick (without citation) that Crick later retracted. Daly insists that Crick believed that the chances of life spontaneously emerging were so "physically improbable (miraculous) that it must have arrived here from space…" (Daly, 2015a, 1)[6]

Daly maintains that the complexity we see in the biological world could not have arisen from pure chance as biologists supposedly claim:

> To preserve the idea of chance as reasonable cause, and thereby escape any notion of Creator or Telos, they argue that although these coincidences are indeed miraculously improbable in a single universe, they would surely happen if there were infinitely many universes. And of course our universe is obviously the one in which the improbable events all happened. If you don't believe that Shakespeare wrote Hamlet, you can claim that infinitely many monkeys pecking away at infinitely many typewriters had to hit upon it someday. (Daly, 2015a, 2)[7]

The argument assumes that the products of evolution spring up out of nowhere with no history or context. Here is a rebuttal of the "pure chance" interpretation of evolution (Rennie, 2002):

> Chance plays a part in evolution (for example, in the random mutations that can give rise to new traits), but evolution does not depend on chance to create organisms, proteins or other entities. Quite the opposite: natural selection, the principal known mechanism of evolution, harnesses nonrandom change by preserving "desirable" (adaptive) features and eliminating "undesirable" (nonadaptive) ones. As long as the forces of selection stay constant, natural selection can push evolution in one direction and produce sophisticated structures in surprisingly short times.

[5] There exists a vast literature on the emergence of life from inorganic compounds. For an introduction see the Wikipedia article "abiogenesis." Other good sources are New Scientist (2017) and Lane (2016).

[6] What Crick really thought: "In the early 1970s, Crick and Orgel further speculated about the possibility that the production of living systems from molecules may have been a very rare event in the universe, but once it had developed it could be spread by intelligent life forms using space travel technology, a process they called "directed panspermia". In a retrospective article about their work [Orgel and Crick, 1993]: "Crick and Orgel noted that they had been unduly pessimistic about the chances of abiogenesis on Earth when they had assumed that some kind of self-replicating protein system was the molecular origin of life." Wikipedia, "Francis Crick"

[7] Rennie (2002) gives a rebuttal of the monkeys with typewriters argument:

> As an analogy, consider the 13-letter sequence "TOBEORNOTTOBE." A million hypothetical monkeys, each typing out one phrase a second on a keyboard, could take as long as 78,800 years to find it among the 2613 sequences of that length. But in the 1980s Richard Hardison, then at Glendale College, wrote a computer program that generated phrases randomly while preserving the positions of individual letters that happened to be correctly placed (in effect, selecting for phrases more like Hamlet's). On average, the program re-created the phrase in just 336 iterations, less than 90 seconds. Even more amazing, it could reconstruct Shakespeare's entire play in just four and a half days.

The life-mind discontinuity claims that humans are a unique creation of God and given special privileges and responsibilities. Human consciousness and self-awareness cannot be explained by natural causes. Daly believes that humans transcend the laws of nature that govern other species:

> Those ecological economists less enthralled by neo-Darwinism see humans as fundamentally different, as part of the larger evolved creation to be sure, but a special creature who, like it or not, is in charge of the larger creation, because far more than other creatures, humans reflect the image, albeit a broken image, of their Creator. (Daly, 2022, 12)

A principle of ecological economics is that humans and the human economy are subject to the same scientific laws that govern other species. This is the basic message of Daly's mentor, Nicholas Georgescu-Roegen in *The Entropy Law and the Economic Process* (1971). Daly's creationism leads him to reject this basic insight.

Irreducible complexity

A favorite argument against evolution given by creationists, particularly those associated with the Discovery Institute, is that life is too complex to have arisen without a creator.[8] Daly's embrace of the creationist irreducible complexity argument is clear:

> Even in the realm of materialism it [neo-Darwinist theory] faces some serious glitches. I refer to the problem of how it happens that many interdependent parts of a complex organ, each of which has no independent survival value, can both occur and be retained until the whole organ is assembled into a complete functioning unit, which only then can contribute to survival and thus be selected. (Daly, 2013b, 1)

Darwin, like modern biologists, understood that mutations (he called them "sports"), do not cause evolution by themselves. Natural selection picks out the useful mutations and these are retained and passed on to future generations. Biologists recognize sources of variation other than mutations, for example, genetic drift, hybrids and horizontal gene transfer. The importance of this to ecological economics is that Daly's anti-evolution views are central to his conception of the SSE. For him, a sustainable economy will come about through "transcendence"—human divineness transcends the laws that bind other species (Daly, 2021)—not through the evolutionary unfolding of a complex, continually changing system.

[8] Here is a summary of the irreducible complexity argument (Wikipedia):

> Irreducible complexity (IC) is the argument that certain biological systems with multiple interacting parts would not function if one of the parts were removed, so supposedly could not have evolved by successive small modifications from earlier less complex systems through natural selection, which would need all intermediate precursor systems to have been fully functional. Irreducible complexity has become central to the creationist concept of intelligent design (ID), but the concept of irreducible complexity has been rejected by the scientific community, which regards intelligent design as pseudoscience. Irreducible complexity and specified complexity are the two main arguments used by intelligent-design proponents to support their version of the theological argument from design.

Teach the Controversy

This is a Discovery Institute initiative to promote the teaching of creationism in public high schools. The strategy, also called the wedge strategy, is to place creationism on the same footing as accepted evolutionary science. The mantra is: "Why can't we hear both sides?" The intent is to create controversy where none exists. The claim that intelligent design is an alternative to accepted science has been denounced by numerous scientific organizations including the American Association for the Advancement of Science (2013).

A ploy of "teach the controversy" is to claim that neoDarwinian evolution is controversial among biologists. In Daly's (2006a, 14-15) words:

> Macroevolution is an extrapolation of the same mechanism observed in microevolution (random mutation and natural selection) to explain the development of all species from a presumed single ancestor over a long period of time. This cannot be directly observed nor repeated in a laboratory and is an extrapolation. Is it a reasonable conjecture? Certainly. Is there evidence for it? Yes. Are there gaps in the evidence and logical glitches in the theory? Yes. Scientists themselves debate these when they think creationists are not looking.

Here again Daly shows a basic misunderstanding of evolutionary theory and evidence. Speciation has been "observed" in the fossil record as has very rapid speciation as seen in the evolution of cichlid fish in Africa's Great lakes. The Faroe Island house mouse is another example—the new species evolved in less than 250 years after being introduced to the island.

Natural selection is the driving force of evolution, but it is even more powerful than Darwin imagined. Phenomena like epigenetics, hybridization, horizontal gene transfer, and the evolution of evolvability have revolutionized our understanding of evolution (Jablonka and Lamb, 2014). The field of evolutionary biology is one of the most exciting areas in science today (New Scientist, 2017). Daly goes so far as to say that Darwin has lost favor among biologists because of his materialism. He writes (Daly 2002, 195):

> The economic determinism of Marx has now collapsed both intellectually and politically. The psycho/sexual determinism of Freud is increasingly considered pseudo science of the worst kind. The remaining member of the nineteenth century trinity of determinism, Darwin, is still riding high. However, the neodarwinist evolutionary determinism of chance and necessity with its total rejection of purpose and design, is undergoing serious reconsideration in many quarters, even though somewhat underground.[9]

Daly's creationist views on evolution are beyond the fringe of accepted science.[10] Evolutionary biology has a 200-year history of solid theory and evidence based on the contributions of tens of thousands of dedicated scientists hammering out one of the most accepted bodies of knowledge in science.

[9] In a footnote to the last sentence Daly (2002, 196) cites Discovery Institute fellows Michael Behe and Phillip Johnson. For Daly, "reconsideration in many quarters" means by creationists associated with the Discovery Institute.

[10] See the resolution on intelligent design adopted by the American Association for the Advancement of Science (AAAS, 2013).

Intelligent design is a pseudoscience that has no place in ecological economics or the sustainability debate.

Daly's Creationism and his Conception of the Steady State

How does Daly's creationist framework affect his analysis of the steady state? Daly's rejection of evolutionary theory leads him to a concept of the steady state that incorporates the faults of standard economic theory elucidated by ecological economists (1) it ignores basic understandings of the natural sciences, (2) it relies on identifying marginal changes in a near-to -equilibrium system, and (3) it is ahistorical. Daly's creationist pre-analytical vision prevents him from seeing the economic process as an evolving system with contingencies, re-combinations, dead ends, and revolutionary breakthroughs. Here is Daly's basic argument:

1. Scientists cannot explain the origin of life without resorting to the argument that it is the result of random, infinitely many trials and errors without direction or purpose. Claiming that neoDarwinian evolution precludes human agency is the starting point for Daly's argument for a steady state economy. There exists a vast literature on the nature of, and the limits to, human agency. Daly's contribution to this debate is to insist that neoDarwinian evolutionary biology precludes free will.

2. Since evolutionary biologists believe that everything that exists is the result of pure, directionless chance, they cannot legitimately have opinions about anything. Daly's only authority is a 100-year-old reference to the philosopher Alfred North Whitehead's (1925) "lurking inconsistency."

Daly's perceived lurking inconsistency:

> My point for now is that biologists/ecologists who teach a materialist neo-Darwinist worldview to sophomores on Monday, Wednesday, and Friday, and then devote their Tuesdays, Thursdays, and Saturdays to pleading with Congress and the public to enact policies to save this or that endangered species are in the tight grip of a serious inconsistency. (Daly, 1999, 693; 2013a, 2)

As the biologist Alan Holland (2002, 203) puts it in a commentary on a paper by Daly: "To put it bluntly there seems to be no connection at all between Darwinism and the abandoning of criteria for making ethical judgements, nor between Darwinism and the embracing of philosophical determinism." Natural selection does not preclude "choice." Holland (2002, 205) writes:

> …Daly's claim that natural selection makes our choices for us is quite simply a travesty. The associated claim that there is no room for purpose in the neodarwinian worldview is untenable, as is Whitehead's claim, endorsed by Daly, to detect a "lurking inconsistency" in the modern worldview—allegedly, a view of the world as a mechanism which nevertheless contains self-determining organisms. Insofar as natural selection might be viewed as a mechanism, it is a mechanism that fully embraces self-determining organisms.

3. Since materialist evolution precludes direction or purpose, we need objective value as a basis for making judgments about better or worse states of the world. Objective value is given by Judeo-Christian religion.

> But where does our knowledge of objective value come from? I would say from religious insight, specifically in the West from the Judeo-Christian tradition whose historical dominance has been greatly weakened by attacks from the secular intelligentsia, and by its own internal failures and worldly corruptions. At the same time Scientism has taken the cultural place of religion, but promotes a materialist world view productive of power, but devoid of purpose or value. (Daly and Morgan, 2019, 152)

Daly's source for his objective value argument is C. S. Lewis who stated that "A dogmatic belief in objective value is necessary to the very idea of a rule which is not tyranny or an obedience which is not slavery" (quoted in Daly, 2022). Daly's uncritical use of the creationist literature and discredited creationist advocates, and the dubious logic he uses to defend his positions, raise serious questions about his SSE framework. For Daly, the inability to deal with economic growth is a moral failure rooted in neoDarwinian materialism.

4. From objective value to the steady state - Daly's vision of the steady state economy is based on faith in a Creator who has given us a blueprint (objective value) for how to live sustainably.

> Now here I come trying to convince you that what God really likes best is a sustainable or steady state economy. (Daly, 1996, 205)

> Indeed, it is precisely because science and technology have given us such power that the scale of the economy has been able to grow to the point where we must now consciously face the fundamental limits of creaturehood: finitude, entropy, and ecological dependence. Science can help us adjust to these limits in the best manner, but to think that we will overcome them is to claim authority to remake God's Creation on our own blueprint, rather than to maintain and care for it according to God's. (Daly, 1996, 214)

The steady state is a better version of the existing economic system—one more just and less exploitative of the natural world. Daly claims that it is hubris to think we mortals can overcome the limits of God's universe—a hubris centered in the world view of scientific materialism and endless growth. By contrast, we must maintain and care for the steady state according to God's plan.

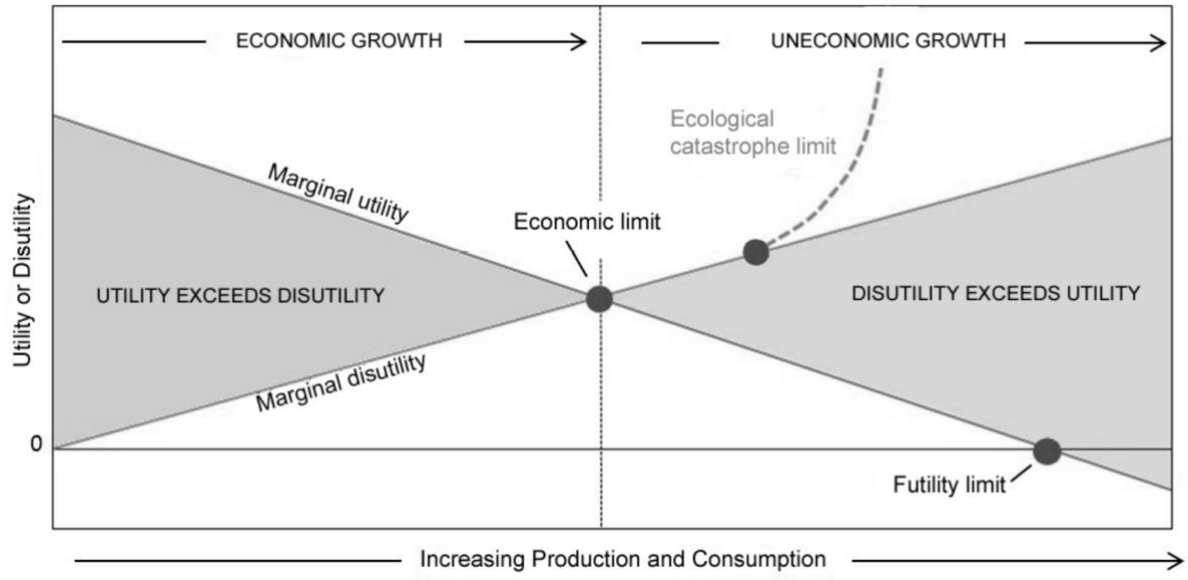
The first step in Daly's path to the steady state is to cap economic activity "at or near existing or nearby levels." After this is achieved, we can determine the optimal scale of this non-growing system.[11]

> [T]he first issue remains to stop the momentum of growth and to learn to run a stable economy at historically given initial conditions. ... But we cannot go into reverse without first coming to a stop. Step one is to achieve a steady-state economy at existing or nearby levels. Step two is to decide whether the optimum level is greater or less than present levels. ... My own judgment on these issues leads me to think we have overshot the optimum. (Daly, 1991, 52)

Figure 2 below shows Daly's (2015b, 6) conception of the temporary steady state (step one).

[11] Following Georgescu-Roegen's (1976, 24) view that "…the necessary conclusion of the arguments in favor of that vision [the stationary state] is that the most desirable state is not a stationary, but a declining state" a large literature exists advocating a declining state (Bonaiuti, 2011).

Figure 2. Daly's Limits to Growth: Finding the Steady State Economy (from Daly 2015b, 6)



On one hand he recognizes the conflict between economic activity and the environment, but he sees this conflict in a linear, mechanical, and non-evolutionary way. Past a certain point (the "economic limit"), economic growth reaches the point where the costs of further growth exceed the benefits. The diagram shows the problems with Daly's comparative static analysis of the steady state. As several writers have pointed out, it is essentially standard neoclassical economics (Pirgmaier, 2017; Spash, 2020; Ziegler, 2007). It is defined in terms of "utility" to humans. It assumes smooth and continuous cost and benefit curves. It assumes there is an optimal level of economic activity and some optimal state of the environment. The "ecological catastrophe" limit is given by a point on the continuous marginal disutility curve, meaning that changes above and below "catastrophe" are small and incremental. Daly (2015b, 6) recognizes that: "Some human activity, or novel combination of activities, may induce a chain reaction, or tipping point and collapse our ecological niche." The problem is that economic activity to the left of the economic limit may lock us into a catastrophic change well before we know what's happening and before we reach the point where MC=MB (where marginal utility equals marginal disutility). Climate change is a case in point. The "futility limit" is where "the marginal utility of production falls to zero." How this is different from the MC=MB "economic limit" is not clear. Both seem to be based on a neoclassical utility function. Both seem to require a social welfare function. Daly's use of neoclassical tools brings with it all the theoretical difficulties associated with standard economics (Gowdy, 2004, 2010; Gowdy and Erickson, 2005; Keen, 2021). How is utility defined and how is it aggregated? Daly's combination of neoclassical economics, and social and environmental critiques of it, is confusing and contradictory. An understanding of evolutionary change—abrupt discontinuous change, contingency, historical lock-in, novelty by combination—is not compatible with comparative statics and marginal analysis. Daly's static view of the economy as a near to equilibrium system leads him to fall back on standard economic theory which describes an economy that can be manipulated by tweaking prices and regulating market failures. What would the steady state look like? It would be a static system frozen in time and space. Some ecological economists will object to say that Daly insisted that a steady state economy can develop without growing (sustainable development). Georgescu-Roegen was merciless in his attacks on the steady state and sustainable development:

> Understandably, the meretricious optimism of these two slogans—steady state and especially sustainable development—attracted legions of converts who gathered into one "global" forum after another to enhance the reputation of the promoters of the bill. There must be some special decorative profit in any such agitation since many large corporations sought a badge of distinction by founding [*sic*, "funding"?] such activities. (Georgescu-Roegen, 1989, 168)

From the beginning, Daly's recommendations about the steady state were based on concepts from standard economics—use non-renewable resources at a rate equal to or less than increases in efficiency or the discovery of substitutes and use renewable resources at a rate less than the environment's assimilative capacity (Daly, 1973, 1977). The prospects for the world's governments to unite behind binding agreements to impose absolute limits on resource extraction and pollution are dim. Daly's specific stewardship steady state policies include cap-auction-trade systems for basic resources, ecological tax reform, a shorter workweek, public ownership of common goods, and stabilizing population at or near current the current level (Daly, 2013c).

According to Daly these policies will bring us to a non-growing economy "at or near existing levels." This is a surprising statement since the current level of human activity is decimating the non-human world and radically destabilizing the earth's climate. Most of these are laudable, although pedestrian, policies. Most are part of standard neoclassical environmental economics and/or a widely accepted progressive agenda. We have no problem with these short-run policies. Their implementation would make the world a better place. Our concern is that Daly's SSE does not explain how the steady state actually functions as a dynamic, irreversible, continually evolving and adapting system, or how it could be imposed on the existing capitalist system. Richard Smith (2010, 121) writes of the steady state:

> But one of the most frustrating aspects of reading Daly's books is this maddening imprecision. If it's not capitalism and it's not socialism, what exactly is it? For a start, who owns it? If we're talking about a modern industrial economy, who owns the factories, the mines, the auto plants, the oil companies, the airlines, etc.? And if this economy is mostly comprised of corporations, owned by investors, what are the implications of such corporate ownership for the problem of growth? And what are the implications of the threat of unemployment if one or another factory has to shut down in order to stop pollution or out-of-control growth, in order say, to get a 'steady state' economy? Daly says almost nothing about such questions.

Again, Daly's problem with evolutionary biology, is that there is no "purpose."[12] In his view, this precludes biologists from having opinions about the state of the world, since they believe that everything is meaningless and thus there is no way to judge "better" or "worse" states. Religion can give us purpose by revealing God's will:

> Is man basically a fallible creature whose salvation lies with his Creator rather than with his own creations? Or is man potentially the infallible creator himself, whose salvation lies in his own creations? The first view of man as fallible creature, ultimately dependent on the Creator, is the view that underlies the SSE. It is the traditional wisdom of the ages, taught by the great religions. The second view, man as a potentially infallible creator seeking salvation in the perfections of his creations, leads

[12] "Purpose" is a human construct. In a religious vision we imagine a God who assigns purpose to his creation. But humans can easily assign purpose to evolution. One could say that the purpose of a living being is survival and propagation of the species. Biologists wisely avoid the term.

> to cosmic vandalism. It is the view, not of great scientists but of third rate devotees of modern scientism, whose numbers are legion. (Daly, 1977, 26)

To summarize, these are the steps to Daly's steady state: Reject modern evolutionary biology because it precludes human agency, reject materialism and replace it with Judeo-Christian "objective value" to give the human presence value and purpose, implement the steady state to fulfill our religious obligation (stewardship) to protect and care for God's creation (Daly, 2015a).

Summary and Commentary

Daly's rejection of neoDarwinian evolution is a major reason for the ambiguity and contradictions in the SSE. We cannot understand biophysical reality with supernatural explanations based on demonstrably false assertions. We need more, not less, of what Daly dismisses as scientific materialism, that is, natural explanations for natural phenomena. Ecological economics was founded on the basic idea that the human economy is part of the larger biophysical universe and that our species is subject to the same laws that apply to all others. The economy is an evolving, one-way system based on the laws of physical production and supported by values and world views, and interlocking systems. What would a materialistic, evolutionary grounding of ecological economics entail?

First, ecological economists must reject Daly's anti-evolution views. His view of evolution is unambiguous. He states clearly that modern evolutionary science should be rejected by ecological economists:

> But in learning from ecologists, we must be beware of going overboard and importing into EE the metaphysical assumptions that many ecologists have often inherited from their parent discipline of neo-Darwinist biology. These metaphysical assumptions of philosophical materialism and determinism, however productive they may be in physical science, are fatal to policy sciences that require the recognition of conscious purpose as causative in the world, and ecological economics is a policy science. (Daly, 2019, 3).
>
> There are many political roadblocks to an ecological economy, but the most fundamental barrier may turn out to be the repugnant metaphysical dogma of materialist naturalism that logically, but blindly, aborts the possibility of policy of any kind. (Daly, 2019, 3)

Few ecological economists would subscribe to Daly's creationism. But few recognize the fundamentalist pre-analytical vision underlying Daly's SSE. Georgescu-Roegen (1971) taught us the importance of physical, scientific laws in the economic process. Evolution is a one-way street of irreversibility, and irrevocable change. Optimal scale is an illusion in a continually changing universe.
Second, addressing our current ecological and social predicament requires a deep historical and materialistic understanding of the evolutionary history of *Homo sapiens* and the human economy. We need not assume predestination to recognize patterns in our evolutionary history that transcend human intentionality. For example, after the agricultural revolution, the same complex cultural patterns and institutions evolved independently in the Indus Valley, the Far East, the Middle East, and the Americas. This convergent evolution suggests that some common underlying forces drove the evolution of complex human societies. To understand where we are and where we might be going requires a deep understanding of our evolutionary past (Gowdy, 2021; Krall, 2022, 2023). Insights from anthropology, economics and evolutionary biology can be used to build theories of social evolution and institutional

change (Wilson et al., 2023; Wilson and Gowdy, 2015). Evolutionary theory should certainly be included in Norgaard's (1989) methodological pluralism.

Third, Daly's reliance on the neoclassical model of marginal change in a near-to-equilibrium system is inadequate to understand major evolutionary transitions. Like other highly evolved complex systems, the human economy consists of interrelated, integrated and mutually reinforcing ultrasocial relationships (Gowdy and Krall, 2016; Krall, 2023).

Fourth, the notion of agency and free will needs to be addressed by ecological economics. An evolutionary and materialist world view suggests that human agency does not fully explain social evolution. Individuals have some degree of agency and self-determination, but complex socio-economic systems not so much (Gowdy, 2021; Krall, 2022). The large and growing literature on the role of agency (and the lack of it) in evolutionary change is a fertile field that can help us understand the limits to relying on individual initiative as a basis for public policy.

Daly's positive contributions to the limits-to-growth debate are undeniable. Given the forces now in play, human society will be radically different in a few hundred years, maybe in a few decades. It seems certain that climate change will lead to a major evolutionary transition in human social evolution. Given this, even if it were possible, should we institute polices to preserve the existing system or should we try to anticipate the likely trajectory to a system in a new balance with the natural world? Given the magnitude of environmental disruption, especially climate change and the decimation of non-human species, together with increasing political and social instability worldwide, it's hard to be optimistic about our immediate prospects. If we take a long-run view, however—and by long-run we mean the next few hundred years—there is reason to hope. Nature has a way of resolving imbalances. Evolutionary biology, not fundamentalist religion, is the best guide to understand the place of our species in the biophysical universe, and to formulate policies to address our current predicament as the Anthropocene unfolds.

> Undoubtedly, the current growth must cease, nay, be reversed. But anyone who believes that he can draw a blueprint for the ecological salvation of the human species does not understand the nature of evolution, or even of history—which is that of a permanent struggle in continuously novel forms, not that of a predictable, controllable physio-chemical process, such as boiling an egg or launching a rocket to the moon. (Georgescu-Roegen 1976, 25)

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