Dissipative Structure Analysis and Ecological Disorganization: A Critique Drawn from Ecological Marxist and Treadmill-of-Production Approaches

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Abstract: Among environmental sociologists, ecological Marxists argue that there is an association between capitalism and ecological destruction/disorganization. This argument suggests that capitalism and nature are in contradiction with one another, so that the expansion of capitalism necessarily results in the destruction of nature. Green criminologists expand on this point and argue that ecological disorganization generates legal and illegal green crimes and injustice. This capitalism–nature association suggests that solving the current ecological crisis would require replacing capitalism. In contrast, the dissipative structure analysis (DSA) argues that capitalist nations pass through phases of development and that as advanced capitalist nations age, the level of ecological destruction they cause becomes attenuated. If true, this outcome suggests that capitalism might solve the problem of ecological destruction by aging. This article reviews these two theoretical arguments, exposes the limitation of the dissipative structure argument, and suggests that future research is required to completely address dissipative structure assumptions. A major limitation of the dissipative structure analysis is its failure to account for the effect of developing capitalist nations on the expansion of ecological disorganization. Trend charts are employed to illustrate the limitations of the DSA hypothesis concerning reduced ecological disorganization.

Keywords: capitalism–nature contradiction; ecological disorganization; environmental sociology; green criminology; dissipative structure analysis; treadmill of production

1. Introduction

It is widely noted in several disciplines that there has been a growing ecological crisis for the past half century. In 1980, one of the important arguments linking ecological crises to economic production, treadmill-of-production theory (ToP), was posited by Schnaiberg [1]. This view suggests that capitalism in particular runs on a treadmill that seeks to constantly increase profits through increased production. At the same time, this system requires increased ecological inputs and, through production, generates expanded ecologically adverse outputs (i.e., pollution), so that capitalism continually accelerates ecological disorganization through both resource withdrawals and the addition of pollution to ecosystems. More recently, green criminologists have drawn upon ToP observations to discuss the treadmill of crime, examining how green crimes and harms are produced by the political economic structure of post-WW II global capitalism [2,3]. In the green criminological view, the adverse impacts of capitalism on ecosystems (i.e., ecological disorganization) is defined as a crime against nature from an ecological rather than a legalistic perspective [2]. This approach draws upon ecological Marxism to develop a political–economic green criminology (PEG-C), which suggests the existence of a long-term association between capitalism and the generation of green crimes and injustice as defined by the production of ecological disorganization [3]. An important implication of ecological Marxist and green criminological views is the hypothesis that the continued increase in ecological destruction will accompany...
the global expansion of capitalism [4]. In this view, the future life course of capitalism could lead to such extensive ecological disorganization that the stability of the ecosystem becomes threatened and destabilized, leading to a global ecological collapse. This outcome is consistent with the scientific literature on threats to planetary boundaries [5] and decades of research addressing an historical pattern of pollution and resource exploitation [6].

One alternative to the capitalism–ecological collapse hypothesis suggests that as capitalism ages and reaches the end of its life course (i.e., its “growth plateau” [7]), its ecological impacts will subside. This argument was developed by Matutinovic, Salthe, and Ulanowicz [7], who apply a “general developmental theory of dissipative structures” to examine the life cycle of capitalism. Drawing on dissipative structure analysis (DSA), they argue that like other kinds of complex systems and life forms, capitalism can be expected to dissipate (i.e., show signs of aging) or to disintegrate over time and, as it ages, produce reduced adverse ecological impacts. They examine this hypothesis employing data on the developmental pathways of the most advanced capitalist nations. Their evidence suggests that as capitalism ages, its ecological impacts diminish. This outcome contains potentially good news ecologically, since the ecologically damaging consequences of capitalism in the future would diminish as the largest capitalist national economies become stagnant.

On its face, DSA arguments contradict assumptions found in ecological Marxist and green criminological literatures drawing on treadmill-of-production (ToP) explanations. ToP theory predicts that capitalism—even as it ages—will continue to generate ecological destruction across its stages and across nations. Thus, in contrast to the potentially optimistic DSA view, ecological Marxist and green criminology posits the pessimistic alternative that capitalism will continue to generate ecological disorganization [2,3], a deepening metabolic rift [8], ecologically unequal exchanges [9], and expanded green crimes and injustice that can only be eliminated by dismantling capitalism [2,3,10].

To assess these opposing positions on capitalism and ecological disorganization and destruction, the current article reviews and critiques Matutinovic et al.’s DSA argument. This critique posits that the decline in ecological disorganization produced by attenuated capitalist development in late-stage capitalist nations (i.e., slowed and declining levels of economic expansion) will be over-ridden by economic expansion and development and increased ecological disorganization generated by expanding capitalist economies in developing nations.

2. Background

ToP theory argues that the pace of economic growth under capitalism accelerated following World War II and constituted a new phase of capitalist production called the treadmill of production [1]. Under ToP-style capitalism, increased production and profitability result from expanded reliance on fossil fuels and chemical energy, which also expands ecological disorganization, defined as ecological destruction linked to accelerated ecological withdrawals of raw materials and the increased addition of pollution to ecosystems [1]. This argument, developed in environmental sociology, has become a central component of the green criminological explanation for ecological disorganization or green crimes, which are defined as legal or illegal behaviors that harm ecosystems and species in those ecosystems [2,10].

Given extensive evidence of the deleterious effects of humans on local and global ecosystems, numerous studies, commentaries, and political and nongovernmental organizations have addressed efforts to curb human-induced ecological harms in the hope of preventing future ecological disasters. Relatedly, studies in the social sciences have examined capitalism, its organizational structure, and its penchant for unrestrained growth as a significant cause of the global ecological crisis [4,11–16]. Numerous empirical studies have highlighted the association between capitalism and the emergence/expansion of several forms of ecological crises (e.g., on ecological footprints [17,18], on oceans crises [19], on biosphere rifts [20], on water pollution [21], on deforestation [22], and on biodiversity [23]). These more radical, structural ecological theories and empirical studies suggest that policies
designed to control ecological disorganization must constrain production and consumption trends associated with capitalism and eliminate capitalism as a guiding economic structure.

These observations raise a related question: if, as suggested, expanded capitalist production generates increased ecological disorganization, might the stagnation or decline of capitalism curb or even retard the production of ecological disorganization? This issue is raised in Matutinvic et al.’s [7] analysis of the growth pattern of advanced capitalist nations from 1983 to 2013. To answer the above question, it is necessary to know if the growth rate of capitalism declines over time and then determine whether that decline is sufficient to reduce the production of ecological disorganization. This issue is examined below.

3. Capitalism in Decline

The above discussion raises the question of whether capitalism is environmentally sustainable. In examining this issue—which involves the connection between capitalism, ecological disorganization, human impacts associated with the Anthropocene, the Great Acceleration, and ecological sustainability—some argue that reorganizing and creating a sustainable capitalism, rather than replacing capitalism, would effectively curb ecological destruction [24] and might include technological innovations that make production more efficient or result in the expanded recycling of waste. This approach assumes that a significant reorganization of capitalism can not only reduce the production of ecological disorganization but is an effective strategy for undoing the extent and forms of ecological disorganization capitalism generated in the first place. Other studies indicate that recessions are linked to a decline in pollution [25], supporting the contention that economic contraction generates beneficial ecological outcomes in the short term.

It should be noted, however, that research on the effect of technology on pollution outputs and other adverse ecological consequences of production suggests that technological innovations not only fail to reduce pollution but in fact may increase pollution. This effect (often referred to as “Jevons Paradox”) was first discovered by Jevons [26] in his 1865 study of the coal industry in the UK. He found that instead of preserving coal, technological innovations in the coal industry increased production and the use of coal. More recently, Huesemann [27] argued that the assumption that technology/science can provide solutions to environmental pollution problems are optimistic and suspect. He indicates that pollution and ecological destruction problems cannot be solved due to what can be called the physics of production. For example, both the law of the conservation of mass and the second law of thermodynamics suggest that pollution remediation technologies might reduce specific pollution outputs, but at the same time, these remedies would generate other associated adverse environmental impacts. Moreover, he indicated that the law of entropy indicates that it is likely impossible to design large-scale industrial processes that are absent adverse environmental impacts. Huesemann concludes that as a result, “science and technology have only very limited potential in solving current and future environmental problems” [27], p. 287.

Other recent studies are also consistent with Jevons Paradox and Huesemann’s arguments. For instance, Jian, Chen, and Luan [28] recently showed that while robot technology was capable of reducing some pollutants, this effect can only be found when the overall production output increases, so that relative to the output, pollution may fall, while it still increases in the aggregate.

Observing growth patterns in advanced capitalist nations, some argue that the effect of capitalism on ecological disorganization is likely to be attenuated by the natural aging process of capitalism. The idea that capitalism “ages” refers to the long-run history of advanced capitalist nations, which in the largest, and essentially oldest capitalist economies, means that rates of growth have declined [7]. For example, Matutinvic et al. use what they call the “general developmental theory of dissipative structures” to analyze whether economic growth under capitalism reaches a plateau, where economic growth dissipates and may come to a halt. Their approach builds on systems theory, biophysics, and dissipa-
tive structure arguments (DSAs) to examine two inter-related issues. First, they present a rather complex analysis of the development of capitalism over time, using concepts from the physical sciences, which identifies stages of capitalism (see section, the dissipative-structure approach for details). Second, they explore how capitalism and the environment interact, illustrating the deleterious impacts of capitalism on the environment from a DSA perspective. Part of this analysis addresses how the decline of capitalism and the ecological crisis intersect.

Extrapolating from Matutinvic et al.’s approach and empirical analyses, it can be argued that the “natural history” of capitalism suggests it may be in its waning phase—at least in advanced capitalist nations. With regard to green crime, Matutinvic et al.’s argument would imply that the deteriorating growth patterns associated with “the life-course of capitalism” may decelerate or impede ecological disorganization and, hence, avert the need for intervention. In other words, in the DSA view, it may not be necessary to institute policies to constrain capitalism’s growth to reduce ecological disorganization, since this outcome will occur “naturally” because of the dissipation of capitalism over time. Thus, if capitalism ages in the way suggested by Matutinvic et al., then the premises related to the association between continued ecological disorganization and capitalism and the assertion that, therefore, capitalism will continue to accelerate its green crimes against nature would be rejected.

Matutinvic et al.’s assertions also raise related questions. These questions ask whether change in capitalism produced by aging is (A) occurring rapidly enough to significantly interrupt the production of ecological disorganization; (B) is itself sufficient to reduce ecological disorganization to levels that contribute to ecological sustainability in the future; or (C) may be over-run by expanding economic growth and ecological disorganization in lesser-developed capitalist nations as they expand, which also needs to be addressed to draw conclusions about the DSA argument.

4. Will Declining Capitalism Reduce Ecological Disorganization?

The connection between capitalism and ecological disorganization has been addressed in various ways. For example, modernization approaches argue that the updating, modification, and invention of new technology associated with streamlined, efficient production that occurs under capitalism has beneficial ecological outcomes [26]. This argument has also been widely critiqued by environmental sociologists [8,27,28] and challenged by the results of empirical studies [19] and by observations developed from Jevons Paradox [29–33].

A similar argument is posed in the environmental Kuznets curve (EKC) literature. The EKC argument posits that as societies experience economic development, the available economic resource base grows, promoting public demand for enhanced environmental protection. In this view, economic development generates available excess resources that can be used to address environmental problems, which stimulates the public’s demand for increased environmental protection. The EKC argument suggests that historically, there is an inverted “U”-shaped relationship between economic development and pollution. During the upward phase, as economies developed, economic expansion co-occurs with an increase in pollution. Over time, that relationship is attenuated and is followed by a period where economic development and ecological disorganization become disassociated (i.e., decoupled; for a critique, see [34]). Plotting this relationship results in the inverted EKC “U” curve between economic development and pollution. Studies have both supported and rejected the EKC argument [35,36], and evidence depends on the nations and time periods examined. These studies produce contradictory results, suggesting the limits of this view, and include research revealing “N”-shaped economy–pollution curves, where the development–pollution relationship is attenuated and then accelerates [37]. Empirical assessments of the EKC hypothesis by environmental sociologists [38,39] have shown the limitations of this view.

A related argument posits an economy–environment decoupling effect, meaning that over time, the effects of economic production on environmental degradation become attenu-
ated (i.e., decoupled). Here, again, extant research questions whether economic development produces environmental decoupling and significantly lessens the production of ecological disorganization [39–42]. Finally, there is also a more general argument that technologically generated economic efficiency decreases the quantity of the natural resources used in production, again implying attenuated ecological disorganization over time. This argument was first critiqued by Jevons [26], who studied coal consumption in the UK following the introduction of the steam engine. Jevons found that new, more efficient production technology did not decrease but rather increased the consumption of coal, and over time, the generalized relationship between the introduction of economically efficient production techniques and expanded ecological consumption became known as “Jevons Paradox”. This outcome, also known as the rebound effect, has been widely discussed and assessed [34] and suggests that economic development and efficiency in itself does not lessen ecological disorganization and can, in fact, expand ecological disorganization [43–45].

In short, it can be argued that through the treadmill of production, capitalism has contributed to the “Great Acceleration” of ecological disorganization during the Anthropocene era. This observation is consistent with scientific and sociological research. In contrast to observations from ToP theory and ecological Marxism—which suggest continued ecological disorganization as capitalism proceeds on its historical path—however, DSA suggests the potentially optimistic observation that the degrowth of capitalism as it ages should limit its impacts on ecological disorganization.

The DSA position suggests that the growth of capitalism, by continually consuming nature, reduces the availability of ecological resources, and these natural resource limits result in a rebound or detrimental feedback effect, so that the growth of capitalism is slowed by the ecological limits it created [7]. In theory, this slowed growth would reduce ecological disorganization. Whether or not the aging and reduced economic growth of advanced capitalist nations is itself sufficient to significantly reduce global levels of ecological disorganization requires further analysis.

5. The Dissipative-Structure Approach

As Matutinovic et al. note, there is extensive literature on the physical and ecological impediments to economic growth starting from the 1970s. The most widely known work, The Limits to Growth [5], garnered widespread interest when it was published and has been cited approximately 34,000 times (Google Scholar, June 2024). The ecological limits to growth have been examined in numerous studies. In an early analysis, Limits was criticized by researchers who questioned its outcome assessments [46]. A more recent reanalysis employing updated data (1970–2000) illustrates that Limits’ conclusions—which specified a mid-21st century global ecological collapse—remain plausible [47]. Scientific studies of the stability of “planetary boundaries” [4] support similar conclusions. Concerns with an ecological collapse are also found in other relevant pieces of literature, including steady-state economics [48]; ecological Marxism [8,11]; economic degrowth analyses [49–51]; environment–economy decoupling analyses [34]; ecological rebound effect/the Jevons Paradox assessments [52]; and in Georgescu-Roegen’s [53] environmental entropy model, which gave rise to the field of ecological economics.

Building upon this type of argument, and observations concerning declining growth rates in capitalist economies, Matutinovic et al. [7] developed their “general theory of dissipative structures” (p. 18). The DSA is drawn from natural systems theory and is applied to their view of “autocatalytic dynamics models” [54] of economic development and growth.

An autocatalytic process is one in which the catalyst or cause of the reaction is also one of the products of the reaction, and, therefore, the process is self-sustaining until the reactants are exhausted. Autocatalytic arguments are drawn from physics and chemistry and have been related to a well-discussed issue in the scientific literature, the production of entropy. Ulanowicz and Hannon [54] noted that while there has been significant scientific controversy surrounding the idea of entropy related to the second law of thermodynamics,
the second law has generally been found to be valid, except in the case of ontogenesis (i.e., the developmental life course of an individual being within a given species) or phylogenesis (i.e., the manifestations of diversity within species). Ulanowicz and Hannon, however, argue that these exceptions occur only when the interaction of an individual within a species or a species more generally is taken out of context, and ontogenesis and phylogenesis are not connected to their effects on the surrounding environment. They argue that when contextualized appropriately (i.e., when the interconnection between species, individuals, and the environment is considered), evidence of increased disorder over time (entropy) is normally observed.

The dispute concerning the interaction of species–individuals with the environment in relation to entropy centers on whether species have minimal or “other” effects on entropy production. Ulanowicz and Hannon argue this is important ([54], p. 182), because to exert a minimal ecological effect, a species must behave “conservatively”. The early 20th century biophysicist, Alfred J. Lakota, who quantified Darwin’s approach to natural selection, stated that rather than act conservatively in resource-abundant environments, species/individuals in resource-abundant environments still compete for resources, and those adept at competition will be more likely to survive by increasing their resource consumption. Because successful species survive through increased resource consumption, their behavior expands entropy. Relatedly, Ulanowicz and Hannon argued that the introduction of “living species” into an environment will expand the amount of entropy in that system. Ecological Marxists associate this same outcome with capitalism, arguing that the tendency for capitalism to grow and consume natural resources increases entropy—and, one could argue, being successful at capitalism requires expanded production and consumption, and, therefore, successful capitalist economies must generate increased entropy over time. This produces a situation where the competition between capitalism and nature over resources (capitalism consumes natural resources; nature needs a natural resource base to reproduce itself) becomes key to understanding the contradiction between nature and capitalism and how the expansion of capitalism produces the contraction of nature [4,12,13].

In addition, Ulanowicz and Hannon [54] noted that to survive, species perform work, and while work preserves order within a species, it also generates disorder and entropy in the larger environment. Thus, one can argue that species–individuals that perform more work to enhance their survival cause greater environmental entropy. Moreover, given that in the natural world, species are interdependent, inter-species competition and increased resource use can produce positive feedback or serve as autocatalysis. This means that enhanced activity (e.g., work) in a competitive environment by one species (or individuals) stimulates enhanced activity/work in another species (or individual), which increases entropy production. We will return to this idea in the discussion and relate these observations to competition under capitalism and how competition and the organization of capitalism can promote enhanced entropy and disorder and how under treadmill capitalism, increasing ecological disorganization emerges and expands.

Building on these arguments, Matutinovic et al. [7] note that there are three general stages of organization in systems theory that relate to entropy production and adverse ecological impacts: immature, mature, and senescent states. They relate this observation to the stages of capitalism, or what can be called the aging of capitalism in a particular nation. The immature stage of capitalism began with the Industrial Revolution and involved “intensive, exponential growth as measured by energy and GDP” ([7], p. 19). During the immature stage, intense, expanded competition and use of environmental resources accelerated entropy. During the mature stage, growth becomes limited due to the development and structure of global capitalism. Under global capitalism, growth begins to be impeded by the “closed natural system”, which has definable physical limits and consequently defines the limits of sustainable economic production and consumption. In the senescent stage (a biological term related to aging and its association with a deterioration in functioning), several conditions emerge that are evidence of the aging of the economy and ecosystem. These include diminished returns on economic investments, disintegrated infrastructures,
reduced energy inflow, and degraded ecosystems. Degraded ecosystems, in turn, suffer irreversible damage associated with extensive resource use and widespread pollution, leading to an increased reliance on recycling and the reorganization of production. During the declining senescent stage, they suggest that it is possible (but not necessarily true) that alternative forms of economic organization emerge that seek to create a “steady state” trajectory with decreased entropy production sufficient to support “an advanced civilization” ([7], p. 19).

They argue that the history of capitalism essentially appears as an autocatalytic cycle, where competition produces more economic activity over time, escalated resource consumption, expanded work, and more entropy. As entropy increases, environmental-resource availability and quality declines, affecting the ability of capitalism to continually expand in an unlimited manner. This observation relates to their division of capitalism into the three stages above. They provide no specific dates associated with each phase. Nevertheless, based on their argument, one can posit that their long-run history of capitalism, spanning hundreds of years, produces varying degrees of ecological disorganization in each phase. One can hypothesize that theoretically, the capitalist development–ecological disorganization curve would appear as a very long environmental Kuznets curve in this view. Using the approximate historical moments in Matutinovic et al., one would expect to see expanded economic growth and ecological disorganization from about 1760 to the end of the 19th century, slowed growth in the early 20th century, followed by expanded growth with increased economic globalization, and then a levelling off in growth in the late 20th century. Whether ecological disorganization follows the same pattern, however, remains an open question, and there is evidence reviewed above related to ecological footprints, decoupling, and the environmental Kuznets curve which indicates that disorganization does not diminish as capitalism ages.

Here we draw attention to the latter phase of capitalism among advanced economies posited by Matutinovic et al. This argument implies attenuated ecological disorganization as advanced capitalist nations age and become senescent. We suggest that the association between ecological disorganization and capitalism more generally, however, remains in question. Is an economic decline beneficial ecologically? Moreover, is economic dissipation among advanced capitalist nations sufficient to protect the global ecosystem from further, serious damage? This issue is examined below.

6. Dissipative Structures: A Critique

Above, we reviewed Matutinovic et al.’s [7] explanation of the interactions between species and the environment with respect to competition, entropy, and autocatalytic cycles derived from the DSA. This argument has been applied to the relationship between phases of capitalism and the production of ecological disorganization over time. In general, these observations appear to fit with discussions of ToP theory in relation to the production of green crime [2] and with broader descriptions of the relationship between capitalism and ecological organization in the ecological Marxist literature [4]. Below, we examine these arguments in greater detail, showing limitations of DSA arguments.

Competition is a key feature of capitalism and part of Matutinovic et al.’s [7] DSA arguments. Recall that Matutinovic et al. argued that species–individuals compete with one another for available resources and that species–individuals adept at competition experience an increased likelihood of survival while enhancing adverse ecological impacts (i.e., entropy). This argument, derived from Darwin’s theory of evolution, has also been applied via Social Darwinist arguments [55]. In this view, the struggle for survival can modify organisms and their behavior in ways that promote survival but at the expense of the stability of ecosystems. Recall also that Matutinovic et al. suggested that species/individuals most adept at competition would survive by escalating their consumption of natural resources. In the end, they also argued that this process would lead to the increased impact of species–individuals on the environment through the expansion of entropy but that as capitalism ages, this ecological effect would dissipate.
At this level of analysis, the role of competition in capitalism is not entertained in ToP theory. The dissipative competition argument suggests that individuals (perhaps capitalist and other high-income earners) and species (here, possibly the capitalist class) that are better able to compete enhance their survival. In this view, “better able to compete” is linked not only to survival but to the excessive consumption of ecological resources [14,17,18,22,28]. Joining these arguments and referring to capitalism, this view suggests that individuals or classes better able to compete consume more. Under capitalism, “survivors” earn higher incomes and consume more. This observation does not mean that capitalism is morally preferable but merely that this description fits with empirical observations of outcomes under capitalism. For example, research in the US indicates an 81% increase in premature mortality among Black as opposed to White households and that in Black households, income was 40% lower [56], suggesting that those with lower incomes or a reduced ability to compete for resources within capitalism are less successful when it comes to survival. Moreover, research for the period of 1960–2015 indicates that consumption has risen steadily for median-income and moderately low-income families in the US, despite a low-level growth in real wages [57]. The latter finding is consistent with the DSA approach, suggesting that low- and median-income wage earners appear to continually increase consumption in response to the forms of competition engendered by American capitalism and hence also increase the production of adverse ecological outcomes. Evidence of a competition/consumption effect can also be seen across nations in studies of the ecological footprints of nations [14,17,18,21,27,28].

The connection between capitalism and competition has been widely discussed. Clifton [58], for example, noted that all theories of capitalism refer to the concept of competition, whether they view competition as perfect (i.e., the opposite of a monopoly market) or imperfect. We mention this distinction, because it is relevant to our interpretation of Matutinovic et al.’s argument. Under conditions economists define as constituting “perfect competition”, competition within a market segment is extensive; within this segment, the commodity being produced and sold is identical; each firm’s market share is relatively small. Because the market share is small, barriers to market entry (i.e., amount of capital) are relatively unrestrained. Under monopoly circumstances, conditions are the opposite (imperfect competition exists). The effects of monopoly competition, which has increased over the historical long-run of capitalism (i.e., the number of monopolies and monopoly effects increase), leads to declining commodity prices, which leads to an increase in the demand for commodities. This benefits firms in a monopoly sector, as profits rise (the multiplicative effect of price and quantity increases profit [59]). Also, an increased demand for commodities stimulated by the concentration of monopoly capital leads to an increase in ecological-resource consumption as demand rises and also to increased entropy/ecological disorganization.

Under imperfect competition, however, a new capitalist market contradiction emerges. As prices decline and demands increase, production increases, and the availability of raw materials declines. This situation increases production costs through expanded resource scarcity, which affects the marginal costs of production [59] and hence commodity prices. Nevertheless, if prices and demands remain adequate, production increases [59], which suggests more work is applied (either physical labor and/or fossil fuel/chemical and machine labor), which also expands ecological entropy/ecological disorganization. This process continues until the difference between market prices and production costs (i.e., the marginal costs of production) deteriorate (or as economists might say, returns to equilibrium) and establishes conditions where profit is minimized, and it is no longer attractive to expand production to achieve minimal profit. In other words, the kinds of competition for raw materials and for consumers in a monopoly sector causes long-run, escalating expenditures on energy for production, as well as expanded ecological withdrawals and, because production is escalating, increased pollution. Combined, these factors increase the level of ecological disorganization, or as green criminologists would suggest, the forms of
green crime produced by manufacturing industries [2,3], unless conditions in monopolized markets dissuade capitalists from further investments in production.

How do the above observations relate to Matutinovic et al.’s [7] arguments? As they noted, increasing competition, which in this case also involves considering the expansion of consumer demand for commodities, accelerates the quantity of work applied and hence the generation of entropy. As they also note, capitalism has various stages of growth. In the related literature, it has been posited that each stage of growth under capitalism has an internal cycle associated with capital investments, disinvestments, and reinvestments—or what are called Kondratieffian waves [60] or phases in the social structure of accumulation (SSA; [61,62]). In the SSA approach, each wave has three parts: expansion, decay, and contraction. Building on Matutinovic et al.’s arguments, it can be posited that the extent of entropy production will vary across and within waves of each long-wave cycle as the economy expands, decays, and contracts. As these waves emerge and develop, the volume and extent of ecological disorganization produced ebbs and flows, but the level of production at the end of a Kondratieffian wave is typically higher than at the beginning of the wave (except, perhaps, when a recession/depression coincides with the end of a cycle).

In ToP theory, the above argument suggests that over the long-run of a series of economic cycles (Kondratieffian waves), there would be an upward trend in ecological disorganization, and the appearance of a cycle of ecological disorganization within each economic cycle comprises expanding and then contracting ecological disorganization (see Figure 1). Theoretically, one could hypothesize from the PEG-C literature [2,3] that green crime potentially follows the same cyclical patterns. As an example, consider this short-term trend for toxic releases in a sensate economy in the US from 2013–2022 (Figure 2). This figure shows a small decline in toxic emissions over a decade. Compare this to Figure 3, showing an increase in the number of polluting facilities and toxic-waste emissions in an expanding economy in South Korea. These examples are limited and affected by data availability, and additional data is required to establish the regularity of the patterns depicted here. An issue that emerges with respect to selecting data to illustrate different contentions is two-fold. First, data reporting and public access to data are in some macrolevel sources at least a few years behind the period we might like to include. Second, some of the trends being described were likely interrupted by other social and economic factors that might impact trends and make them more difficult to interpret in a simple fashion. Recently, this included the global recession linked to the COVID-19 pandemic. An additional, no-less-important concern here was selecting data that also overlapped with the data used by Matutinovic et al. [7].

An additional consideration comes from research on the Environmental Kuznets Curve (EKC) and whether economic development produces a reduction in pollution. The EKC argument states that as societies develop, the volume of pollution they generate increases but later levels off and then declines with continued economic expansion and the modernization of production. The ToP perspective, in contrast, would suggest that as capitalism develops, the quantity and rate of ecological disorganization continually expands (though the rate of expansion might slow for various reasons, including limits on raw-material availability or difficulty obtaining raw materials or, in some cases, one could argue, the use of technologies that reduce energy inputs into the system or recycle more waste materials). Following Matutinovic et al.‘s DSA approach, it could be argued that in the later downward EKC period, pollution/ecological disorganization would decrease over time as capitalist economies age, which again contradicts the ToP hypothesis.
**Figure 1.** Hypothetical trend in ecological disorganization within and across long cycles/social structures of accumulation (authors' example).

**Figure 2.** Historical trend in toxic releases for different pollutants, US, 2013–2022 (source: US Environmental Protection Agency 2023, [https://www.epa.gov/trinationalanalysis/trends-releases](https://www.epa.gov/trinationalanalysis/trends-releases), accessed on: 5 May 2023 [63]).
The first issue is whether the EKC argument is correct, that is, whether there is substantial evidence that as capitalism modernizes, pollution and ecological disorganization decreases. There is evidence supporting both sides of this argument, and results depend on the nations studied, modelling assumptions, and the dependent variable selected for assessment [65–67]. In our view, typically, what seems to be found is an EKC–DSA interaction, so that the predicted decline in pollution is seen in older capitalist and not expanding/developing capitalist economies. The second issue is that much of the EKC literature does not address the economy–environment decoupling effect [34] between declining pollution/ecological disorganization in economically advanced nations and the expansion of pollution/ecological disorganization generated by economic expansions in developing nations. In the latter view, declining economic expansions in developed nations may, as Matutinovic et al. suggest, reduce the volume of pollution and ecological disorganization generated in those nations. The rub, however, is that at the same time, economic expansions and increased production of pollution/ecological disorganization are accelerating in developing economies [34]. In short, if an EKC effect exists, modernization and declining pollution/disorganization in some nations are offset by economic and pollution/disorganization expansion effects in other nations.

A related issue is whether modernization impedes pollution. Modernization arguments suggest that over time, economic modernization involving enhanced or new technology reduces ecological disorganization. In Matutinovic et al.’s DSA model, the modernization argument is replaced by a stage decay approach discussed earlier. In this view, the long-term economic decline is likened to processes that occur in nature that are affected by conditions such as feedback and decay. As they note, “In nature . . . self-amplifying autocatalytic processes . . . provoke their opposite—decelerating loops—that rein in tendencies for unfettered growth and move a system back toward balance . . . [This] constraint usually appears either as finite rate of supply to one or more of the interacting groups, or there is attenuation of feedback due to increased dispersal of effect along the causal loop. There are no theoretical reasons to overlook the possibility that eventually, multiple negative feedback loops should arise in a complex adaptive system like a capitalist economy” ([7], p. 20). In this view, whether or not economic modernization is occurring, the economic system reaches a point where contraction is forced by exogenous factors—which,
in the case of economic expansion, is the supply of nature or natural-resource availability. Matutinovic et al. examine this possibility employing economic data from 1983 to 2014 for a sample of 35 nations. In addition, drawing on prior research, they argued that the close empirical relationship between the expansion of the gross domestic product and per capita energy consumption implies that OECD nations will be unable to significantly stimulate economic growth in the senescent stage, because the costs of increasing energy consumption are economically and ecological unfeasible, leading to an economic decline which would re-establish an equilibrium between capitalism and nature.

While Matutinovic et al.’s argument allows us to understand how advanced economies decline over time, and can be employed as a substitute for the modernization argument and its assumption of continued economic expansion, they do not offer a direct test of this argument in terms of whether economic dissipation would diminish global ecological disorganization more generally (i.e., lead to a reduction in pollutants other than carbon dioxide), nor do they take into account the opposing effect we proposed above concerning the growth of ecological disorganization and development in non-core capitalist nations. As will be illustrated below with carbon emissions, the link between economic decay and a reduction in ecological disorganization is displaced by the effects of economic expansion and carbon-emission growth in developing nations. This suggests that there are multiple or different development–ecological disorganization patterns occurring simultaneously across segments of nations in different locations in the global economy. The latter outcome is consistent with the proposition in ecological Marxism that capitalism and nature are in contradiction with one another [11] and that capitalism will always, in the aggregate, produce ecological disorganization and instability due to that contradiction [12].

7. Materials, Methods, and Results

Matutinovic et al.’s DSA approach suggests that the dissipative tendencies of capitalism lead to declining economic productivity. They provide empirical evidence supporting this argument using economic-trend data for the world’s most developed nations. Drawing from ecological Marxism, we proposed that this decline in advanced capitalist economies’ expansion and the concomitant decline in ecological disorganization is offset by economic expansion and increased ecological disorganization in developing nations. That is, given production cycles and the tendency for capitalist economies to seek expansion, economic development and ecological disorganization dissipation in the world’s more advanced economies may be offset by economic expansion in lesser-developed/developing nations. If developing nations’ economic expansion, production, and consumption are accelerating more rapidly than those processes are declining in advanced economies, then economic dissipation in advanced economies will be insufficient to impede ecological disorganization globally, because it is being counteracted by economic expansion in developing nations. This possibility is examined relative to carbon dioxide emissions across high-income and middle-income nations below.

To explore their DSA argument, Matutinovic et al. employed two samples of highly developed nations: one with 10 “early industrializers” and another with 35 Organization for Economic Cooperation and Development [OECD] nations. Using that data, they found evidence supporting a DSA effect. Our critique of DSA suggests that reduced ecological disorganization in aging capitalist nations would be offset by the growth of ecological disorganization in developing countries. To test this proposition, we plotted metric tons of carbon dioxide emissions against the gross domestic income per capita for two groups of nations defined by the World Bank as high-income nations (N = 78) and middle-income nations (N = 109; https://data.worldbank.org/country, accessed on: 2 March 2022; see Figures 4 and 5). We plotted these results for the same period (1983–2014) employed by Matutinovic et al.


Examining trends in Figures 4 and 5, evidence of a leveling-off in carbon emissions in high-income nations is evident, along with a fairly continuous gross domestic income (GDI) growth. This is consistent with Matutinovic et al.’s argument. Compare this outcome, however, to Figure 5 for middle-income nations, where there is evidence of growth in both the carbon emissions and GDI.
More specifically, carbon emissions in high-income nations increased by 32.8% from 1983 through 2004 and declined by 5.1% from 2004 through 2014 but increased over the entire period (1983–2014) by 26 percent. For middle-income nations, carbon emissions for the same periods increased by 103.5% and 57.6% and by 221% overall. For the entire period, carbon emissions in middle-income nations increased nearly five times as much as emissions in high-income nations. Thus, while Matutinovic et al.’s DSA shows the expected decline in carbon emissions/ecological disorganization among high-income nations, two additional points should be highlighted. First, our sample of nations was larger than Matutinovic et al.’s and was not restricted to “early industrializers” or to the larger (N = 35) set of advanced economies of OECD nations. Thus, our sample includes nations excluded from Matutinovic et al.’s dissipative stage among the advanced capitalist economies, and this inclusion might affect the curve depicted for carbon emissions over time. Nevertheless, broadening the sample shows a long-term continuation in ecological disorganization as measured by carbon emissions.

Second, the purpose of comparing carbon emission trends across high- and middle-income nations was to determine whether the dissipative effects of aging capitalism in highly developed nations on carbon emissions/ecological disorganization was offset, as we hypothesized, by economic expansion and increased carbon emissions in middle-income nations. The World Bank data indicate that this is indeed what occurs, and that, therefore, the optimistic assumption that economic dissipation in advanced economies might be sufficient to significantly reduce ecological disorganization must be rejected, indicating that economic aging does not serve as an inadvertent form of ecological protection.

8. Discussion

Explanations from ecological Marxism have been employed to define and examine the types and extent of ecological harms and forms of ecological disorganization that occur in society as related to the expansion and organization of global capitalism. Borrowing from this view, green criminologists have developed this theoretical and empirical analysis of ecological disorganization and redefined ecological disorganization as a green crime against nature [2,3,67]. One implication of this approach for studying green crime is the hypothesis that the continued expansion of the economic treadmill of production will produce an increase in ecological disorganization over time. Prior empirical research has addressed that connection in green criminology supports that contention. Moreover, green criminologists have demonstrated that efforts to control pollution through environmental enforcement does not slow the treadmill of production [3,68–70], while research in ecological Marxism demonstrates that processes endemic to capitalism produce expanded ecological disorganization through expanded ecological footprints [17,18], the expansion of different types of metabolic rifts [19,20], and the effects on biodiversity loss [23] as the economy and environment fail to decouple [41]. Taken together, these pieces of literature suggest an expectation for continued ecological disorganization during the Anthropocene era as the Great Acceleration continues, despite regulatory efforts to control the treadmill of green crime.

Juxtaposed with this argument, research and theories on ecological/economic modernization, the environmental Kuznets curve, and dissipative structure analysis suggest that over time, the effect of capitalism on nature (i.e., ecological disorganization) is attenuated and that reductions in ecological disorganization result from transformations in the nature of capitalism including, for example, enhanced technologies that reduce and reuse raw-material supplies and energy consumption in the production process. As noted above, prior research examining whether economic and technological developments associated with capitalism reduces ecological disorganization finds those arguments to be lacking theoretically and empirically.

For its part, dissipative structure analysis suggests that over time, as capitalism ages, (1) developed economies slow down, (2) economic expansion becomes limited by both internal and external conditions, and (3) the result is less ecological disorganization. Theo-
retically, this argument is plausible, given that cycles of economic production are dependent
on natural resource availability, and as resources dwindle, acquiring and extracting raw
materials becomes more difficult and expensive, raising production costs which may reduce
demand and consumption. These observations suggest that perhaps the aging of capitalism
will reduce production and consumption and create conditions that inadvertently reduce
the use of ecological resources and, therefore, produce less ecological disorganization in
aging portions of the global capitalist world economy.

The DSA argument, tested by Matutinovic et al., illustrated the slowing of economic
growth and a reduced ecological and energy consumption among a limited sample of
nations. This analysis, however, did not account for the hypothesis that a decline in ecolog-
cal disorganization might be offset by escalating ecological disorganization generated by
developing nations where economic production and consumption are expanding. In other
words, the decline of ecological disorganization in advanced capitalist nations may reduce
adverse ecological outcomes, but this result is no cause for optimism given the opposing
tendencies in developing nations. Using World Bank data across 188 nations, we illustrated
that while advanced economies are indeed slowing, economies in less-developed nations
are expanding and increasing their resource consumption and pollution levels, resulting in
an escalation in ecological disorganization. Using trends, we showed that economic expan-
sion in medium-income nations caused increasing carbon emissions—a form of ecological
disorganization—that exceeded carbon emission reductions in high-income nations.

In addition, Matutinovic et al.’s analysis did not measure what can be called a ‘pollu-
tion displacement’ effect. This effect occurs when advanced nations restructure econom-
ically to take advantage of global wage differentials and resource availability and move
production to less-developed/delaying nations. This displacement of pollution effects
has been linked to the structure of export patterns in the global world capitalist system,
where pollution created by manufacturing in less-developed nations is linked to commod-
ity exports to core nations [71,72]. This process has been linked to the global structure of
ecologically unequal exchanges (EUEs; [9,14]). EUE theory argues that the structure of the
global capitalist economy allows developed nations to exploit environmental resources in
less-developed nations and, in the process, to externalize ecological additions (i.e., pollu-
tion) and ecological withdrawals onto lesser-developed nations, which then bear the brunt
of consumption tendencies in developed nations [73].

While this article has examined the dissipative structure argument and how this
argument relates to the relationship between capitalist development and pollution outputs
or the expansion of ecological disorganization, it can be argued that this discussion has
omitted a consideration of what is happening in less-developed nations or among other
groupings of nations, such as those traditionally defined as belonging to the global South.
Here, we can only address this issue in limited fashion to illustrate how an extension of our
discussion links to related research on ecological disorganization patterns as those patterns
related to North–South locations.

Traditionally, the North–South divide reflected a pattern of ecologically unequal ex-
changes where wealthier, economically central Northern nations exploited the raw materials
(and often the labor) of Southern nations, increasing the wealth of Northern nations at the
expense of Southern nations. As Givens et al. [74] note, this position suggests that “through
the structure of international trade, wealthier, more powerful countries within the Global
North have disproportionate access to natural resources and sink capacity—the ability of
the environment to absorb waste products—within Global South nations”. Moreover, it is
important to note that historically, Southern nations competed with one another to deliver
raw materials and labor at the lowest prices, leading to competition and conflict between
Southern nations. Over time, some Southern nations built on their relationship with the
North and developed more expansive economies and, in turn, became exploiters of other
Southern nations that remained in the global economic periphery ([75], pp. 27–28). With
respect to the subject of this paper, this observation suggests that Southern nations that
move upward in the world economic hierarchy are likely to expand ecological exploitation
as a pathway for enhanced development, an argument that counters the modernization claims that economic development reduces ecological disorganization. As noted in the related literature, core capitalist nations contribute to and benefit from this situation and are facilitated through core institutions such as the World Bank and the International Monetary Fund [76].

Given the above observations and related assessments, some argue that the old dialogue about competing interests of the global North and South no longer applies to, for example, climate change or other environmental policies at the international level. This argument suggests that the old North–South model represents “a static and no-longer accurate view of global environmental inequality” ([76], p. 373). In this revised view, the global South is no longer in similar positions where all nations in the global South can be said to share the same developmental path and the same relationship with each other and the North. Rather, nations defined as belonging to the global South have become “politically and economically fragmented” ([76], p. 373). Understanding global environmental issues and policies and outcomes, such as ecologically unequal exchanges, require a more “nuanced understanding of the global South as a complex and changing set of relations reflecting shifts in the historic world order…”([76], p. 373)).

9. Conclusions

While our assessment suggests limitations in the DSA (for an alternative argument, see [77]), this approach nevertheless opens up some interesting future research possibilities. Given the already complex nature of the arguments examined here, we have not suggested how the DSA and the metabolic rift analysis relate to one another [78], which may be applied to the related literature as well (e.g., on marine ecosystems [23], and on ecological unequal exchanges [13]). Exploring these additional intersections provides a wealth of materials for expanding the theoretical and empirical political economic analysis of green crimes.

As noted, Matutinovic et al.’s analysis only examined carbon emissions, and their argument could be tested with other pollution data to assess whether the aging of capitalism reduces other indicators of ecological disorganization. Confounding effects in pollution-trend data in recent years (e.g., the Great Recession and COVID-19’s economic effects) would need to be addressed. Such studies should also control for the effects of additional variables to determine whether the composition of nations used to represent advanced capitalist economies—or even lesser-developed nations—affects the outcome. These controls would include assessing the portion of economic production generated by manufacturing, the service and the agricultural sectors, and might also include other economic measures related to ecological destruction, such as measures of the mining and forestry industries. Similar studies might also examine other outcomes across nations, such as species richness or endangerment and extinction (e.g., [23]).

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