



The World-System and the Earth System

Struggles with the Society/Nature Binary in World-Systems Analysis and Ecological Marxism

Alf Hornborg

Lund University

alf.hornborg@hek.lu.se

Abstract

Efforts to conceptualize the role of asymmetric resource transfers in the capitalist world-system have been constrained by the emphasis on surplus value and the labor theory of value in Marxist thought. A coherent theory of ecologically unequal exchange must focus on asymmetric flows of biophysical resources such as embodied labor, land, energy, and materials. To conceptualize these flows in terms of “underpaid costs” or “surplus value” is to suggest that the metabolism of the world-system can be accounted for using a monetary metric. This paper rejects both labor and energy theories of value in favor of the observation that market pricing tends to lead to asymmetric resource flows. The Marxist labor theory of value is an economic argument, rather than a physical one. In acknowledging this we may transcend the recent debate within ecological Marxism about whether “nature” and “society” are valid categories. Nature and society are ontologically entwined, as in the undertheorized phenomenon of modern technology, but should be kept analytically distinct. Since the Industrial Revolution, technological progress has been contingent on the societal ratios by which biophysical resources are exchanged on the world market. The failure among Marxist and world-system theorists to properly account for this central aspect of capitalist accumulation can be traced to the pervasive assumption that market commodities have objective values that may exceed their price. Instead of arguing with mainstream economists about whether market assessments of value are justified, it is more analytically robust to observe that market valuation is destroying the biosphere.

Keywords: ecologically unequal exchange; society/nature distinction; theories of value; ecological Marxism; technological progress



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Twenty years ago, Timmons Roberts and Peter Grimes (1999) observed that world-system theory over the previous two decades had largely neglected physical aspects of global environmental issues. They explain why world-system theorists had “missed the green wave” by referring to “an unfortunate cultural split” among leftist academics between those fighting for social justice and those prioritizing environmental protection. Although sharing common roots in the political struggles of the 1960s, they argue, the anti-imperialism movement and the back-to-the-land movement had different priorities. This is a valid observation on the divergent trajectories of red and green anti-capitalism in the United States, but as I hope to show in this article, there are also deeper structural reasons for the general failure to integrate social and natural dimensions in leftist critiques of the modern world order. These structural reasons pertain to how the categories “society” and “nature” tend to be delineated in modern ontology.¹

As Roberts and Grimes note, Stephen Bunker’s (1985) efforts to achieve such nature-society integration were a “lone voice” arguing that the inequalities in world-systems could in part be attributed to unequal exchange of “energy values” between cores and peripheries. To make that argument, Bunker was compelled to contradict the Marxist labor theory of value (cf. Bunker 2007),² which had been foundational to earlier definitions of unequal exchange (Emmanuel 1972; Amin 1976). Both before and after Bunker’s (1985) contribution, most world-system analyses have assumed that capital accumulation in core areas can be accounted for in terms of asymmetric transfers of surplus value, and that surplus value can only derive from the exploitation of human labor. As surplus value in Marxist theory is defined as the difference between the economic cost and output of labor-power – that is, between the exchange-value of labor-power and the exchange-value of its products – world-system analysts have conceptualized transfers of surplus value in monetary terms. It has thus been difficult for them to theoretically assimilate Bunker’s assertion that core-periphery asymmetries can derive from physical flows such as the unequal exchange of energy. Not only does his assertion appear to contradict the labor theory of value, it also implies that unequal exchange should be gauged in other than monetary terms. When Bunker (1985: 12) proposes that underdevelopment is “more fully accounted for by the laws of thermodynamics than by theories of politically enforced unequal exchange,” he is obviously referring to the physical metabolism of societies rather than merely to their uneven flows of exchange-values. He explicitly refers to “unbalanced energy flows between different regions” (1985: 245). However, he states

¹ By “modern ontology” I mean the way modern people understand reality to be constituted. A central feature of modern ontology is the distinction between society and nature, not merely as analytical aspects but as discrete and bounded phenomena. Whereas the world-system has been studied by social sciences, the Earth System has been the territory of natural sciences. Convinced that the discourses on the world-system and the Earth System would need to be integrated with each other in the Anthropocene, I organized a conference in Lund in 2003 to address the topic of “World-System History and Global Environmental Change”. A total of 41 papers were subsequently published in two volumes (Hornborg and Crumley 2007; Hornborg et al. 2007).

² Marxists frequently assert that Marx’s labor theory of value merely represents the logic of capitalism, rather than Marx’s own conviction, but this is contradicted by Marx’s ([1867] 1976:151-152) comment that Aristotle had been unable to *see* the “common substance” of all value as labor because ancient Greek society was founded on slavery rather than a capitalist mode of production.

that the underlying problem is that “values in nature have been systematically undervalued” (1985: 31) and concludes that such asymmetric physical flows could be made more balanced by raising monetary compensation so as to “slow the flow of energy to the world center” (1985: 252). In extending the conventional Marxist definition of unequal exchange, Bunker proposes that the asymmetric flows of embodied energy result from market valuation in much the same way that the market organizes asymmetric flows of embodied labor (cf. Emmanuel 1972).³

Bunker’s perspective underscores how the uneven biophysical metabolism of world society is a result of market pricing. Most of his subsequent work on social metabolism focused on flows of raw materials rather than energy (e.g., Bunker and Ciccantell 1999; 2005), but he continued to emphasize how the extraction of resources in the periphery has been fundamental to capital accumulation in the core. Bunker and Ciccantell argue for a “new historical materialism” and a “recasting of world-systems theory to highlight its material and environmental bases” (1999: 120). In indicating how flows of money organize uneven flows of biophysical resources, Bunker’s approach integrates a critique of capitalism with an ecologically framed critique of the metabolism of world society. An important issue raised by his “natural values” approach is the extent to which it implies a modification of a classical Marxist view. If not just “labor value” but also “values in nature” can be undervalued, as Bunker suggests, this is difficult to reconcile with the Marxist labor theory of value.⁴

The contradiction raised by Bunker recurs in voluminous debates on the relation between energy and surplus value in Marxist thought (cf. Martinez-Alier and Naredo 1982; Foster and Burkett 2004; Burkett and Foster 2006; Foster and Holleman 2014; Hornborg 2015; 2019a). It highlights the fundamental question of how we conceptualize “value” and the role of value in the metabolism of world-systems. This issue continues to generate debate on how to theorize the relation between global ecology and global inequalities (e.g., Moore 2015; Foster 2018; Foster and Burkett 2016; 2018; Gellert 2019). This article discusses some of the problems raised in these deliberations. A central problem is the implicit assumptions about objective monetary values that are conveyed in assertions that commodities are “underpaid” or “undercompensated” in market exchange. As world-system analysis is strongly rooted in Marxist theory, the theoretical issues

³ Although he does not mention Bunker, Burkett identifies an “eco-Marxist” school of thought wishing to generalize “the Marxist theory of exploitation to include not just the exploitation of labor but of nature as well” (2003: 139-140). In this school he includes, for instance, Deléage (1994), Salleh (1997), and Brennan (1997).

⁴ Although Burkett (2003) attempts to clarify the distinction between Marx’s treatment of natural “use-values,” on the one hand, and the land or energy theories of value espoused by the Physiocrats and some ecological economists, on the other, Marx’s approach to the role of natural resources in capitalism is ambiguous. As Burkett shows, Marx drew on insights of the Physiocrats on the ability of agricultural laborers to produce over and above their own wages (2003: 143, 146-147, 150), or there would be “no (agricultural or nonagricultural) surplus value” (2003: 146). In this sense, Burkett continues, Marx acknowledged that “surplus value has a natural basis” (2003: 146). From a Marxist perspective, however, the Physiocrats and modern theorists of natural values are mistaken in confusing nature’s “use-values” with monetary exchange-values. This distinction nevertheless begs the question of what “use-values” really are, and with what metric they ought to be measured (cf. Hornborg 2019b).

raised by proponents of an “ecological Marxism” and Marxist conceptions of “unequal ecological exchange” (Foster and Holleman 2014) are of central relevance to the world-system concept. These issues have come increasingly to demand our attention as we struggle to grasp how social and ecological systems are intertwined in the so-called Anthropocene (cf. Malm and Hornborg 2014).

Energy, Value, and Unequal Exchange

As Roberts and Grimes (1999) observe, the fact that world-system analysis is rooted in historical materialism would seem to make it an ideal point of departure for accommodating environmental aspects of capitalism and development. However, its pervasive failure to do so suggests that our conventional notion of “materialism” is not synonymous with a concern with biophysical aspects of society. A “materialist” outlook generally implies an allegiance to the perspective of economics, rather than to natural science, and mainstream or neoclassical economics is notoriously impervious to perspectives acknowledging natural constraints on economic growth. The difference between these two senses of materialism is important and has significant implications for our understanding of Marxist theory. To conceptualize the substance of unequal exchange – the asymmetric flows that sustain hierarchical civilizations and world-systems – as “surplus value” is to inadvertently subscribe to the tenets of mainstream economics. Even though it refers to quantities of embodied labor, and even though Marx asserts that “labour-power itself is energy” (Marx [1867] 1967: 215), the Marxist concept of surplus value is an abstraction that can ultimately be measured only in money. Sergei Podolinsky’s (1883) attempt to persuade Marx and Engels that the labor theory of value had thermodynamic implications was decisively rejected by Engels as well as modern proponents of ecological Marxism (Martinez-Alier and Naredo 1982; Foster and Burkett 2004; Burkett and Foster 2006).⁵

Marx was clearly influenced by David Ricardo’s discourse on labor as the source of exchange-value. Although his analysis of capital accumulation as exploitation certainly challenges mainstream understandings of economic growth, Marx’s economic theory remains couched in concerns with the allocation of exchange-values. Marxist concerns with social justice continue to focus on the emancipation of the industrial worker, rather than on the asymmetric global flows of resources that are embodied in the industrial machine. In Marxist theory, the only possible source of surplus value is human labor. A world-system analysis faithful to standard Marxist economic theory is thus inherently incapable of deriving processes of uneven capital accumulation from

⁵ Podolinsky in 1880 sent to Marx a draft of an article arguing that the labor theory of value is compatible with an energy theory of value, an argument that Engels later dismissed. Martinez-Alier and Naredo (1982) deplore this early “divorce between Marxism and ecology,” suggesting that Marx and Engels were simply “perplexed” by Podolinsky’s analysis, whereas John Bellamy Foster and Paul Burkett have repeatedly endorsed Engels’ verdict that Podolinsky was confusing economics with physics. Engels’ comments on Podolinsky reveal how the foundational Marxist conviction that human labor is the source of all surplus economic value is inextricably connected to a complete disregard for the global, distributive implications of technological progress. In both mainstream and Marxist thought, the augmentation of labor productivity (i.e., greater energy mobilization by means of increasingly advanced “productive forces”) is viewed as a politically neutral gift of nature, rather than an index of asymmetric global resource flows.

asymmetric transfers of natural resources. For the same reasons, it is inherently incapable of understanding technological intensification—the development of the “productive forces”—as contingent on asymmetric resource flows.

There is no question that flows of exchange-values are what organize the material asymmetries and inequalities of world-systems, but it is analytically misleading to conceptualize unequal exchange in terms of transfers of surplus value. Viewed as a total, socio-metabolic process, the accumulation of steam technology in nineteenth-century Britain was the product of a concentration of biophysical resources from different parts of the world, orchestrated by price relations. Advantageous prices on the world market provided opportunities for British entrepreneurs to procure, in exchange for their manufactures, commodities representing greater quantities of embodied labor, land, energy, and materials than were embodied in their exports. What was asymmetrically transferred to the core of the British Empire was not simply “surplus value” but material, biophysical resources. Those rising net transfers of resources (the requisite labor, land, energy, and materials embodied in metal ores, fiber, timber, lubricants, food, etc.) sustained Britain’s nineteenth-century economic growth not merely in terms of the accumulation of *money* capital, but more concretely as the expanding *physical* capital of an increasingly industrialized nation. The accumulation of such physical capital—what I have called “technomass” (Hornborg 2001)—is as amenable to the perspectives of natural sciences such as thermodynamics as are processes of growth in biomass. Nevertheless, such physical dimensions of economic and technological growth often appear to be as irrelevant to Marxist “materialism” as they are to mainstream economics.

I am thus inclined to agree with Roberts and Grimes when they remark that “there is quite little by way of basic theoretical foundations bridging world-system theory and the environment” (1999: 62). Although Marxist theory and historical materialism represent significant efforts to integrate social and natural science, the gap between economics and ecology continue to reproduce the ontological boundary between “society” and “nature” in the modern worldview of Marxists and non-Marxists alike. We tend to be unable to conceptualize the interaction of social and natural aspects as analytically distinct factors rather than as one being subsumed within the other. An insidious illustration of this is the inclination of social scientists to phrase biophysical phenomena in terms of phrases derived from economics. Economic metaphors powerfully shape our thinking about our natural environment. Obvious examples include notions such as “ecosystem services,” “ecological debt,” and “natural capital,” but the pattern recurs even in the most serious attempts to rethink our ways of framing human-environmental relations. Roberts and Grimes thus assert that the capitalist world-economy scatters “ecological costs” unequally throughout the globe (1999: 63), that it is “overtaxing” the global ecological base (1999: 64), and that it relies on “subsidies from nature” (1999: 73-74). In the same vein, Wallerstein explains the source of ecological destruction in terms of “the necessity of entrepreneurs to externalize costs,” suggesting that the “lack of incentive...to make ecologically sensitive decisions” is a specific feature of capitalism (1999: 9). O’Connor (1998) frames the ecological problems of capitalism in terms of increasing “production costs.” Moore writes that the secret of capitalist civilization has been to not “pay its

bills” (2015: 87), and that greenhouse gas emissions illustrate how the atmosphere is “put to work as capital’s unpaid garbage man” (2015: 101). Like Wallerstein, Moore also refers to the “externalization of biophysical costs” (2015: 162). All such phrases implicitly suggest that ecological processes can be conceptualized in terms of monetary balance sheets. Such conceptual colonization of ecology by economics is a pervasive feature of the field of environmental economics but appears to organize our thinking about human-environmental relations even among the most heterodox of approaches.

Of more fundamental importance is the fact that any reference to economic value—as in “surplus value” and arguably even “use-value” (cf. Hornborg 2019b)—must assume a monetary metric. By extension, so must any claim that a commodity is “underpaid,” “undercompensated,” or “cheap”. To refer to the dissipation of resources under capitalism as the appropriation of “cheap” or “unpaid” nature, as Moore (2015) does, implicitly suggests that natural resources have an objective monetary value in excess of the sums spent by capitalists in procuring them.⁶ It also suggests—much like neoclassical economics—that proper pricing would be able to rectify the imbalance. However, value is not a property of nature, but a social relation. It is one thing to say that the pricing of commodities—including labor—organizes asymmetric flows, but this does not mean that the substance of those asymmetric flows is economic value. Asymmetric flows may contribute to the accumulation of a productive infrastructure capable of yielding an expanding output of economic values, but this is not equivalent to saying that the resources that are embodied in infrastructure have objective values that exceed their price. What is asymmetrically transferred from peripheries to cores are biophysical resources, not values.

The incompatibility of the labor theory of value with a materialist theory of ecologically unequal exchange is illustrated by Foster and Holleman’s (2014) contradictory attempt to enlist the latter as an integral component of Marxist theory. Their endorsement of Howard T. Odum’s efforts to establish a “scientifically based value system” (Odum 1988: 1132) is deeply paradoxical. Odum’s argument on “emergy” and “transformity”⁷ explicitly proposes an energy theory of value⁸ and mentions Podolinsky among Odum’s intellectual ancestors, but Foster has elsewhere emphatically rejected energy theories of value in general and Podolinsky’s version in particular (Foster and Burkett 2004; Burkett and Foster 2006). To argue that Podolinsky’s approach is

⁶ Moore occasionally acknowledges that “no metric can capture the differentiated activity of the web of life” and that “calls for capital to pay the ‘true costs’ of resource-use” are an impossibility, amounting to a “call for the abolition of capitalism” (2015:145), yet his concepts of “cheap” and “unpaid” nature evoke the notion of capitalists striking lucrative deals on the market, as if nature was somehow worth more than its price.







⁷ Odum defines “emergy” as “the energy of one type required in transformations to generate a flow or storage,” while “transformity” is “the amount of energy of one type required to generate a unit of energy of another type” (1988:1135).

⁸ Odum’s ambition to establish an energy theory of economic value is particularly evident in his assertion that, “if total annual emergy use measures the real value, then it is the basis for the gross national product” (1988:1136). However, he recognizes that “price is often inverse to the contribution of a resource” and that higher emergy-to-dollar ratios are “found in rural and undeveloped nations,” where money thus “buys more real value” (1988:1136). Elsewhere (e.g., Odum and Arding 1991) he interprets unequal exchange between core and peripheral nations in terms of asymmetric transfers of such “real” (emergy) values.

irrelevant to Marxist theory while Odum's is inspired by Marx himself is incoherent, to say the least. It is easy to understand, however, why Foster found Odum's argument so congenial. As Lonergan (1988) showed, theories of unequal exchange based on deviations of prices from values, whether conceived in terms of embodied labor or embodied energy, are "quite similar." Although their distinct worldviews "present almost insurmountable obstacles [to] any cooperative effort or joint dialogue," Marxist and energy systems approaches to unequal exchange both posit that prices deviate from values in international trade (Lonergan 1988: 141-142). "While commodities exchange at prices," Lonergan agrees, "it seems clear that they do not exchange at equal 'value'." He confirms that unequal exchange is not only "the very essence of capitalism" in Marxist theory but equally central to proponents of the maximum power principle and concludes that "the methods used to measure unequal exchange are identical" (Lonergan 1988: 141-142). No wonder, then, that Foster and Holleman (2014) were able to posit a "Marx-Odum dialectic." But the problems are formidable. Why all those efforts by Foster and Burkett to completely dismiss Podolinsky? Why have they consistently argued that the "use-values" that are underpaid and asymmetrically transferred to core areas of capital accumulation should be understood as the "natural-material" aspects of commodities (Foster 2014; Burkett [1999] 2014), that labor-power is "an energy subsidy for the capitalist" (Foster and Burkett 2008: 6), and that Marx had presented an "energy income and expenditure approach to surplus value" (Burkett and Foster 2006: 126)? How could such "natural-material" energy flows be measured in dollars? Why do Foster and Burkett criticize Podolinsky for mixing up economics with physics while in their own publications repeatedly phrasing exploitation in physical terms? Why is it important for them to portray Marx's theory of capital accumulation as so thoroughly steeped in thermodynamics?

The conundrum exposed by Lonergan is that theories of unequal exchange conceived in terms of underpaid values must apply monetary metrics. The posited net transfers of value from peripheral to core nations are thus quantified in dollars. Given how contested and controvertible the concept of "value" is among different schools of economics, theories of unequal exchange based on positing underpaid values are easy to dismiss as ideological constructs. In contrast, a theory of ecologically unequal exchange that empirically identifies asymmetries in international transfers of biophysical resources (cf. Dorninger and Hornborg 2015) should be taken more seriously, even by neoclassical economists. Instead of saying that commodities do not exchange at "equal value," as Lonergan summarized the approach common to Marxist and energy systems theorists, a more robust argument is to jettison the notion of "real values" altogether and observe that market pricing leads to asymmetric biophysical flows. Such flows of embodied energy, land, materials, and labor must be measured in non-monetary metrics like joules, hectares, tons, or person-year equivalents. This appears to be the only way to navigate between the two opposite fallacies of positing an objectivist theory of value, on the one hand, and ignoring the economic significance of objective, biophysical aspects, on the other. The former fallacy is illustrated by labor and energy theories of value, the latter by neoclassical economics. A robust theory of ecologically unequal exchange must transcend all these fallacies (Fig. 1).

Fig. 1. The role of concepts of value in different schools of economic thought.

	EMBODIED BIOPHYSICAL RESOURCES ('NATURE')	VALUE	MONETARY MARKET PRICE ('SOCIETY')
Neoclassical economics	(IRRELEVANT)	VALUE (UTILITY) 	PRICE
Marxist economics (Marx)	EMBODIED LABOR 	VALUE 	PRICE
Ecological economics (Odum)	EMBODIED ENERGY 	VALUE 	PRICE
Ecologically unequal exchange	EMBODIED RESOURCES 		PRICE

Ambiguities and controversies in ecological Marxism

The theoretical impasse of ecological Marxism, as highlighted in the recent divergence between Moore (2015) and Foster (2018), deserves the careful attention of world-system theorists aspiring to address environmental aspects of global capitalism. The contour of this confrontation is both ironic and revealing. Let me begin by recalling how Moore (2000a) many years ago chided me for having suggested, in an article in this journal (Hornborg 1998a), that Marx's labor theory of value did not suffice to account for the ecological inequalities of the world-system. In that article, I had argued that we need to bring together perspectives from social and natural sciences to understand the global accumulation of productive infrastructure as an ecological process. Like Bunker (1985), I wanted to complement the Marxist framework by theorizing how "exploitation could also take the form of draining another society's natural resources" (Hornborg 1998a: 173). Moore's (2000a) response was to deny that there was any deficit of such ecological insights in Marxist theory. This reaction was completely in line with Foster's (2000) argument in *Marx's Ecology*, which followed Burkett's ([1999] 2014) *Marx and Nature* in defending classical Marxism against the charges of Promethean productivism and ecological ignorance that had been voiced by several socialist theorists in the 1980s and 1990s. Against this background, it is important to unravel how Moore and Foster have proceeded in their divergent efforts to reconcile ecology and Marxism, and to examine their current disagreement.

Foster's and Burkett's repeated and sustained rejection of Podolinsky's proposal (cf. Foster and Burkett 2016) is based on the acknowledgement that Marx's theory of capital accumulation cannot be reduced to energetics. This observation is unassailable. Although frequently aspiring to relate his analysis to the material aspects of labor and production such as energy metabolism, Marx was ultimately concerned with the social processes through which capitalists are able to accumulate surplus value in the form of monetary profits. Foster and Burkett have struggled to unearth a consistent logic by which energy and money are entwined in Marx's thought, but their efforts are finally unsuccessful. They have shown that Marx was highly interested in energy aspects of labor and production, but they have not clarified how a Marxist analysis could derive monetary profits from inputs of labor energy. Marx was well aware that labor-power could be understood in terms of energy, but his analysis of capital accumulation does not really need thermodynamics. The observation that the cost of keeping a laborer working was lower than the

sum of exchange-values that he or she could produce is an economic argument, not a physical one. It is thus not surprising that Engels was bewildered by Podolinsky's suggestion. To say that the worker is able to produce a surplus above his or her wage is a statement about relative exchange-values on the market, not about physical metabolism. But Podolinsky's intervention is completely understandable, given Marx's explicit ambition to present a scientific and materialist account of the capitalist economy. To dismiss Podolinsky as completely missing Marx's point while ignoring how superfluous Marx's own deliberations on energy are to his theory of surplus value is not fair, particularly as Foster's and Burkett's aim is to show that Marx's analysis was deeply informed by thermodynamics. Their voluminous exegeses of Marx's texts (Burkett [1999] 2014; Foster 2000) notwithstanding, Foster and Burkett have failed to demonstrate that Marx's insights on the material metabolism of human organisms and societies were of fundamental relevance for his analysis of capital.⁹

In several publications, Foster and his colleagues have convincingly shown that the disastrous trajectory of the Anthropocene is the result of exploitative global resource flows geared to profit incentives generated by capitalism (Foster and Clark 2004; Clark and York 2005; Foster 2008; Foster et al. 2010; Clark and Foster 2012; Foster et al. 2019). Their identification of asymmetric global flows¹⁰ of resources such as soil nutrients, foodstuffs, energy, embodied labor, embodied land,¹¹ metal ores, and ocean resources from peripheral to core sectors of the world-system – and the inverse flows of waste including greenhouse gas emissions from core to periphery – usefully establishes the *biophysical* aspect of world-systems. However, the ecological Marxists have not shown how these processes would confirm a labor theory of value. Whether phrased in terms of ecologically unequal exchange (Hornborg 1998b; Dorninger and Hornborg 2015) or metabolic rift theory (Foster 2000; Clark and York 2005; Foster et al. 2010), it is certainly legitimate to frame the focus on asymmetric flows of biophysical resources in terms of the treadmill pursuit of capitalist profits, but the exploitation of natural resources in the periphery is not inherently connected to Marx's foundational analysis of the exploitation of industrial workers. While I wholeheartedly endorse the injunction to “put the issue of imperialism in the Anthropocene” at the center of ecological analysis, recognizing the “deep, systematic division of the world into center

⁹ Of pivotal significance in this context is their “natural-material” understanding of Marx's concept of “use-value,” suggesting that the logic of capitalist exchange-values can yield a surplus by systematically “underpaying” the physical aspects of labor and other commodities (Burkett [1999] 2014; cf. Hornborg 2019b). In suggesting that use-values could be more correctly or fairly quantified in monetary terms than what occurs on the capitalist market, this approach contradicts frequently voiced Marxist assertions that the concept of use-value refers only to non-monetary qualities and even that these qualities may be purely symbolic. To claim that use-values are underpaid is to imply that they have an objective economic value that exceeds their exchange-values and can be expressed in terms of money.

¹⁰ Foster aptly refers to these flows as imperialism (Foster and Clark 2004; Foster 2008; Foster et al. 2019). He defines “ecological imperialism” as “use-value transfers” through the extraction of resources – “without equivalent or reciprocity” – from poor countries (Foster et al. 2019:72), but does not suggest how resource extraction could possibly be reciprocated. If he is thinking of monetary compensation, I would object that higher prices could never reverse the ecological degradation implied by the Law of Entropy.

¹¹ The concept of embodied land can be traced to Borgström's (1965) phrase “ghost acreages” and its influential successor, the “ecological footprint” (Wackernagel and Rees 1996).

and periphery, global North and global South” (Foster et al. 2019:85), I have yet to be convinced that these global ecological asymmetries are necessarily linked to Marxist value theory.

As mentioned, Jason Moore was initially strongly influenced by Foster’s emphasis on Marx’s ecological insights, particularly his concept of metabolic rift. In a review of *Marx’s Ecology*, Moore praises Foster’s “powerful argument for the centrality of Marx’s ecological perspective in his critique of capitalism” and agrees with him that “the degradation of the soil and the degradation of the worker are mutually relational – one cannot exist without the other” (2001: 244).¹² In several early publications, Moore (e.g., 2000b; 2007: 137) consistently applied metabolic rift theory to the environmental history of the capitalist world-system. In his more recent work, however, Moore (e.g., 2011; 2015) has expressed strong doubts about the concept of metabolic rift, suggesting that it reflects an unwarranted ontological dualism separating nature and society as “two entities” or “quasi-independent objects” (Moore 2015:75-76). He complains that “the boundaries between the two units – Nature/Society – are nowhere specified” and laments that the implications of metabolic rift thinking “remain fettered by the very dualisms that Foster initially challenged” (2015:79, 84).¹³

Moore’s own recipe for avoiding dualism appears to be to jettison the distinction between nature and society altogether. This is a position that harmonizes with proposals presented by Latour (1993) and other so-called posthumanists, but is as problematic and contradictory as the posthumanist argument that it evokes.¹⁴ In Moore’s version of Marxism, it means reconceptualizing the capitalist world-system as a “world-ecology” and conflating human labor-power and non-human nature into concepts such as “work/energy.” These efforts to integrate the categories of “society” and “nature” have predictably provoked protests from several Marxists (Foster 2018; Foster and Burkett 2018; Malm 2018).¹⁵ For Marxists, a central problem in Moore’s analysis is that it conflates the harnessing and exploitation of natural resources with the harnessing and exploitation of human labor-power, which to Foster (2018) stretches the labor theory of value “to the point of absurdity”. Indeed, it is difficult to see how Moore’s efforts to ecologize the history of capitalism could be compatible with Marx’s theory of capital accumulation as founded on the

¹² This reading of Foster, of course, raises the question why the exploitation of the worker should be more fundamental to capitalism than the exploitation of the soil.

¹³ In his crusade against dualism, Moore aims to “melt” the solidity of rifts such as “town and country, bourgeois and proletarian, and above all Society and Nature” (2015:84). If his point is that societal polarities such as between town and country or even between classes also are to be viewed as Cartesian constructions, it is very difficult to reconcile not only with Marxism but also with the fundamental core/periphery categories of world-system analysis.

¹⁴ It is noteworthy that Moore (2015:171-172) rejects the concept of Anthropocene as reflecting Cartesian dualism, whereas Bruno Latour – the foremost critic of such dualism (Latour 1993) and an obvious source of inspiration for Moore – emphasizes the concept’s monist implications (Latour 2017).

¹⁵ For the record, apparently in order to depict my former colleague Moore as allied with the economist Robert Costanza, Foster and Burkett’s (2018) counter-attack on Moore contains an absurd fabrication about my “key polemical role as a critic of Odum’s approach within the journal” *Ecological Economics*, incomprehensibly characterizing an article of mine (Hornborg 1998b) as “siding with Costanza.” Anyone who has read that article should know that this is very far from true.

appropriation of surplus value generated exclusively by human labor.¹⁶ Yet, although couched in Marxist jargon and multiple references to Marxist literature, Moore's approach is never explicitly detached from this core tenet of classical Marxism.¹⁷

Moore undoubtedly continues to adhere to a Marxist identity but offers an understanding of capitalism stripped of the labor theory of value. If this had been clearly and concisely articulated in his book *Capitalism in the Web of Life* (2015), it would have made more sense. His point would ultimately have been no more complex than to observe that the capitalist pursuit of monetary profits has historically generated—and been contingent on—an intensifying degradation of the biosphere. This observation can be endlessly documented by tracing such processes empirically through the history of the capitalist world-system—and Moore has certainly excelled in doing so—but in terms of general theory on the logic connecting nature and society we are not likely to get much beyond Georgescu-Roegen's (1971) insight that economic processes simultaneously produce exchange-values and entropy.¹⁸ The production of entropy—for instance, greenhouse gases—is not meaningfully understood as an appropriation of the “unpaid work” of nature, as Moore (2015: 101) suggests. The production of exchange-values necessarily entails a dissipation of biophysical resources, but the amount of monetary values produced cannot be analytically derived from the character and extent of resource dissipation. This means that there can be no theory of economic value based on nature.

The World-System and the Earth System: Ontologically One but Analytically Distinct

Against the background of the various positions reviewed so far, what can we conclude regarding reasonable ways of dealing with the society/nature binary in a world-system perspective on the Anthropocene? How can we merge the distributive and the biophysical dimensions of world society without risking accusations of reductionism, determinism, or Cartesian dualism? In this concluding section, before presenting my own position on these issues, I will reiterate some of the agreements and disagreements I have with the theorists reviewed in previous sections.

¹⁶ Moore does not hesitate to speak of an “ecological surplus” (2015: 95) or to confirm that non-human animals are “central to the production of surplus value” (2015: 93, n. 9).

¹⁷ Moore's struggles to retain an allegiance to Marxism are frequently strained to the point of incoherence, as when he tries to persuade the reader that his ecological approach to value does not contradict the core Marxist conviction that “the substance of value *is* socially necessary labor-time” (Moore 2015: 53; emphasis in original). But on closer examination, writes Foster (2018), Moore's analysis “effectively robs Marx's own approach of all significance.” Yet Moore's efforts to reconcile ecology and economics—nature and society—in Marxist theory are largely based on those of Foster and Burkett, who, in Moore's words, are to be praised for incorporating “an ecologically informed theory of value into historical materialism” (2015: 84). It is precisely this impossible ambition, common to these three ecological Marxists, that leads them all astray. Attributions of value certainly have material consequences, but can never be derived from material reality.

¹⁸ This logic—the aggregate consequences of which *is* capitalism—emanates from the idea of general-purpose money and the self-regulating market (Polanyi 1944). Its inexorable commodification and destruction of land, labor, and money itself—what in Marxist terms is referred to as “the law of value”—will not be alleviated until the societal consequences of the artefact of all-purpose money are acknowledged and politically dealt with (Hornborg 2019a). While much of Marx's work is centrally relevant to this acknowledgement, the analytical efforts of the “ecological Marxists” do not advance our theoretical grasp of the Anthropocene.

Conveniently, the approaches of three of these theorists—Stephen Bunker, John Bellamy Foster, and Jason Moore—are compared and assessed in a recent contribution by Paul Gellert (2019). I will thus take Gellert’s discussion as a point of departure.

Gellert begins by asserting that “each of these scholars contributes to our understanding of ecologically unequal exchange (EUE) built on the basis of unequal power relations undergirding imperialism, capitalist exploitation, and uneven development” (2019: 108). He writes that Bunker “introduced ‘ecologically unequal exchange’ in *Underdeveloping the Amazon*” and that this book was foundational “due to its theoretical development of EUE” (2019: 108).¹⁹ Almost three decades later, Foster refers to “unequal ecological exchange” as “an outcome of the global metabolic rift” (Clark and Foster 2012: 69). As Gellert notes, a common ground shared by Bunker, Foster, and Moore is their concern with “the dialectical interpenetration of ‘nature’ and ‘society’ and the ways in which such ‘socio-natures’ are shaped by capitalism” (2019:108). As we have seen, however, Moore and Foster disagree on whether the concept of metabolic rift implies a form of Cartesian dualism separating nature and society. In defense of Foster, Gellert (2019) notes how difficult it would be to think or write about nature without acknowledging the category of “nature” as something distinct from society. He observes that even Moore, “despite strenuous efforts,” cannot avoid writing in “a dualist modality” (2019: 126). It is obvious that Moore confuses the binary *analytical* distinction between social and natural aspects of phenomena with an *ontological*, so-called Cartesian dualism that treats society and nature as insulated from each other. As Gellert puts it, Moore’s rejection of the society/nature binary even “for purposes of analysis” poses “insurmountable barriers to sociological research” (2019: 127).

Moore’s injunction to adopt a Latourian, posthumanist monism is incompatible not only with the analytical ambitions of historical materialism but also with any attempt to unravel the role of biophysical resource flows in the capitalist world-system. To dissolve the analytical distinction between nature and society is as theoretically unproductive as keeping them ontologically insulated from each other, in Cartesian fashion.²⁰ Paradoxically, in their inability to reconceptualize the global phenomenon of modern *technology* (that is, “productive forces”), all three—Bunker, Foster, and Moore—remain firmly entrenched in the Cartesian dualism that Moore

¹⁹ Actually, Bunker did not use the term “ecologically unequal exchange,” but in 1985 he certainly was a pioneer in rethinking unequal exchange in terms of energy flows (cf. Hornborg 1998b). Much later, inspired by Odum’s insight that discrepancies in market pricing led to asymmetric flows of embodied energy, Foster began using the term “unequal ecological exchange” (Clark and Foster 2012: 69; Foster and Holleman 2014). Moore (2015) has never phrased his observations on the appropriation of “cheap” resources in terms of unequal exchange. Gellert’s comment on Bunker’s alleged “theoretical development of EUE” appears to refer to the notion that there are “natural values” that are systematically underpaid on the market. This is a way of phrasing EUE that Odum, Foster, Holleman, Moore, and many others would probably agree with, but that I have consistently rejected (Hornborg 1998b; 2019a). We are all agreed that capitalism degrades nature, but can we usefully explain this degradation in terms of transfers of “value”?

²⁰ As I have argued elsewhere (Hornborg 2017), “social” refers to aspects of phenomena that are contingent on the uniquely human use of symbols, while “nature” can be defined as referring to non-symbolic aspects.

claims to transcend.²¹ Like human bodies, cultural landscapes, and global warming, advanced technologies are simultaneously natural and social phenomena. We need to retain our capacity to distinguish which aspects of these phenomena derive from nature and which from society, but it would be wrong to classify any of the phenomena themselves as belonging in their entirety *either* to nature *or* to society. What the predicament of the Anthropocene should ultimately be telling us is that it has been a great mistake, ever since the early nineteenth century, to classify technology simply as revealed nature, regardless of its location in the world-system.²² To grasp how the world-system and the Earth System are interfused, we need to see how “technological progress” tends to be contingent on asymmetric global flows of biophysical resources (EUE) that simultaneously generate increasing ecological degradation and increasing inequalities. These flows are orchestrated by the way different commodities are priced on the market, but the flows themselves must be conceptualized and measured in physical terms, rather than as “values” (Hornborg 2019a).

The alarming anthropogenic transformations of the Earth System in the Anthropocene clearly derive from the operation of the capitalist world-system. This predicament prompts us to acknowledge the interpenetration of nature and society at a global scale. The ecological degradation of the Earth System and the increasing socioeconomic polarization of the world-system are two sides of the same coin. To theoretically understand how global ecosystems and social systems are interfused, it will not suffice with theoretical frameworks that are confined to understanding *either* natural *or* social systems, phrased in terms of concepts denoting phenomena belonging to either domain. A truly transdisciplinary perspective will need to combine insights from social and natural science. Of pivotal significance for grasping the Anthropocene predicament are how we conceptualize global human interaction through trade. Mainstream economics is exclusively concerned with the societal aspects of trade, that is the international flows of monetary exchange-values. Neoclassical economic theory thus ignores the material substance of trade. As we have seen, several scholars inspired by Marxism and world-system analysis have attempted to rethink world trade in terms of asymmetric flows of biophysical resources, but all have been constrained by the mainstream assumption that market commodities have an objective value that may exceed their price. Net transfers are phrased in terms of values rather than material substances.

In this paper, I have shown how pervasive this assumption is even among radical critics of the logic of capitalism. Stephen Bunker recognized how asymmetric flows of energy and other natural resources had consequences for the prospects of economic development in different areas,

²¹ Thus, even Moore can incongruously describe technological development in early capitalism as processes through which, “[f]or the first time, the *forces of nature* were deployed to advance the productivity of human work” (Moore 2016: 98; emphasis added).

²² While the mirror image—to classify the economy as insulated from nature—is widely acknowledged as a major fallacy (e.g., in ecological economics), the materiality of technological artefacts tends to automatically assign them to the domain of nature, even in Marxist theory well acquainted with their basis in capital accumulation. As we have seen, Burkett and Foster acknowledge asymmetric global transfers of “natural-material” substances, but choose to speak of them as “use-values” rather than as the biophysical resources out of which technologies are made, and on which their operation depends.

but he conceptualized these flows as *underpaid* natural values. Paul Burkett and John Bellamy Foster have interpreted Marx's concept of use-value as referring to natural-material aspects of commodities that are systematically *underpaid*. The discrepancy between such use-values and monetary exchange-values served as a foundation for Foster's and Hannah Holleman's attempt to theorize unequal ecological exchange, and they found the Marxist concept of use-value closely aligned with Howard Odum's argument on energy value. Finally, Jason Moore has based his deliberations on what he calls world-ecology on the capitalist imperative to appropriate *unpaid* work and energy.²³

All these approaches share the notion that the biophysical resources appropriated for capitalist production should be conceptualized as underpaid values. The category of "underpaid values" is rooted in deeply internalized ontological assumptions derived from the market society in which we are all immersed. All-purpose money thus shapes the way we think even about non-monetary phenomena. In this way, the concept of value subsumes nature within society. But there *are* no natural values, only projections of human valuation onto what are ultimately neutral biophysical entities. To coherently theorize how the societal valorization of biophysical resources is generating ecological degradation at a planetary scale, we must refrain from the anthropocentric inclination to impute value to nature. We must detach our analytical framework from the tenets of our socially constructed ontology, so that we can understand the phenomenon of "value" from the same objective distance as we understand "entropy".

It will not do to construct theories of ecologically unequal exchange that assume that what is asymmetrically traded in the world-system are "underpaid values," as this is to apply social-science categories—referring to sociocultural processes of valuation and exchange—to material flows of biophysical resources. Instead of arguing with mainstream economists about whether market assessments of value are justified, it is more analytically robust to observe that market valuation—which must always reward an accelerating dissipation of resources—is destroying the biosphere. By and large, the more resources that have been dissipated in a production process, the higher the price of the commodities thus transformed. The hegemonic notion of economic "value" obscures the implications of the Second Law of Thermodynamics (Georgescu-Roegen 1971). The idea of universal commensurability—by which products representing dissipated resources can be traded for ever greater volumes of fresh resources – is not only fundamental to capitalism, it shapes the categories even of its most radical critics. General-purpose money conditions us to assume that there is a common metric for assessing all things in terms of their "value," but rather than

²³ Moore's problematic understanding of the society/nature binary is particularly evident in his dismissal of the central role of fossil energy in the capitalist world-system (Moore 2015: 177-180). He asserts that capitalism arose "after 1450" and that this was a watershed "*greater than the rise of the steam engine*" (2015: 182; emphasis in original.) This assertion contradicts not only the convictions of several insightful Marxist theorists (e.g., Altvater 2007; Huber 2008; Malm 2016), who show that the harnessing of fossil energy for mechanical work was crucial to capitalism, but also Moore's own aspiration to transcend Eurocentrism. The accumulation of steam technology in early industrial Britain was not so much the trajectory of a mode of social organization established in Europe in the fifteenth century as a reflection of world-system processes three hundred years later.

understanding money as signifying value, we should realize that it is the other way around: the very notion of economic value reflects our conviction that money is a measure of all things.

None of the theorists reviewed in this article have addressed the peculiarity of general-purpose money as a historically recent cultural artefact that has socioecological consequences of cataclysmic proportions. Precisely for this reason, nor have they achieved a detached view of “technology” or “productive forces” as globally generated “socio-natures” *par excellence*. They have not recognized how the use of all-purpose money serves to conceal, under a veil of fictive reciprocity, the asymmetric global transfers of biophysical resources on which unevenly distributed technological development is contingent. As I have argued at length elsewhere (Hornborg 2019a), to curb the blind and inexorable logic through which ecology and the market interact in generating the uneven and unsustainable growth of fossil-fueled infrastructure, our only chance is to rethink (and recall) the very idea of all-purpose money.

About the Author: Alf Hornborg is an anthropologist and Professor of Human Ecology at Lund University, Sweden. His research has addressed the cultural and political dimensions of human-environmental relations in past and present societies. A central contribution is to understand ‘ecologically unequal exchange’ as fundamental to the existence of modern technology, as theorized in *The Power of the Machine* (2001), *Global Ecology and Unequal Exchange* (2011), *Global Magic* (2016) and *Nature, Society, and Justice in the Anthropocene* (2019).

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