

Nature in the limits to capital (and vice versa)

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Of all the varieties of crisis thinking, ecological crisis is perhaps the least developed. It is certainly the least conceptualized. To be sure, there is no scarcity of empirically rich analyses of biophysical shifts at every scale. But ecological crisis in its popular usage has been an expansive concept, implicating the widest range of human activity. It invokes questions of history, power and capital just as much as those of ecology. And therein lies the source of considerable confusion and uncertainty – not so much about what *might* happen (a necessarily contingent matter), but about what *has* happened, and how that history shapes the possibilities we face today.

Such weak conceptualization stems from a way of thinking with origins in the rise of capitalism, more than five centuries ago, which I will call ‘Cartesian dualism’, extending Descartes’ famous mind–body dualism to the notion that Nature and Society are epistemically, even ontologically, independent entities. That dualism powerfully shapes how we think, see and act upon ‘ecological crisis’ today.

Of several alternatives now emerging, the world-ecology conversation has offered a means of reframing world history as a unity of power, capital and nature.¹ If modern world history is typically viewed as a history of human relations with environmental consequences, a broader synthesis is suggested by four decades of Green thought: modernity does not only act *upon* nature, but develops *through* the web of life. I call this synthesis world-ecology – but not because it is committed to studying the ‘ecology of the world’. Rather, world-ecology is a way of conceptualizing and investigating historical change in the web of life. This optic is at once a protest against the ‘Cartesian’ binary and an alternative to it; the world-ecology perspective engages capitalist civilization as a relation of all nature, including those symbolic and material relations between humans often viewed as unquestionably social. In this perspective, the relations of capital, labour and power move *through*,

not around, nature. Culture and symbolic praxis, too, become ‘material forces’. We are dealing not with Nature/Society but with an ‘unbroken coincidence of being, knowing, and doing’.²

Beyond limits

The ‘limits to growth’ in the capitalist era are neither Natural nor Social – not, at any rate, in the way we usually think of these terms. They are, rather, the limits of capitalism’s strategic relations in the web of life. The ‘object’ of crisis is not a substance but a relation of organizing and reproducing life, power and capital. This perspective comes from seeing the modern world-system as a capitalist world-ecology, joining the accumulation of capital, the pursuit of power, and the production of nature in dialectical unity. This is not the ecology of Nature – with the upper-case ‘N’ – but the ecology of the *oikeios*: that creative, generative and multilayered relation of life-making, of species and environments. Species make environments; environments make species. The philosophical point shapes the historical method: human activity *is* environment-making. And in this observation, nature moves from noun (‘the’ environment) to verb (environment-making). Human organizations *are* environment-making processes and projects; they are shaped by manifold environment-making processes in the web of life. This is the *double internality* of historical change – humanity inside nature; nature inside humanity. (With *humanity* differentiated, not reduced to formless, abstract homogeneity.) World-ecology is not alone in making the broad philosophical argument; but it is distinctive in arguing for the translation of these philosophical positions into methodological premisses, narrative strategies and theoretical frames in which specific forms of human organization – capitalism especially – are producers/products of the web of life. The present argument is intended as a series of openings, an invitation to dialogue – not as a new orthodoxy.

World-ecology therefore contrasts sharply with the conventional sorting of Social and Natural limits and crises. Consider the usual catalogue of the forces behind biospheric change, some version of which finds a place in nearly every survey of ecological crisis: industrialization, urbanization, economic growth, capitalism, imperialism, overpopulation, overconsumption, and a great many beyond. Mainstream and radical scholars prefer different factors and different concepts, but all share the same premiss: Society (humans without nature) and Nature (ecologies without humans) are the basic units of global change. Thus, the distinctive quality of these driving forces is the assumption that human activity and human organization somehow form prior to the awful environmental consequences that follow from that activity. In environmental studies today there is a clear movement away from Cartesian dualism, but only up to a point. For those fields focusing on regional change – such as political ecology and environmental history – a relational approach finds growing resonance. For those who study global change, however, Cartesian dualism has been empowered, unfolding as if four decades of the critique of dualism never occurred. Our big concepts of global change – capitalism, imperialism, industrialization, commercialization, and so on – remain safely insulated from the critique of dualism.

The resilience of Nature/Society dualism means that too many scholars – and activists – continue to look for the causes and consequences of capitalist crisis through a seventeenth-century lens. Nature/Society doesn't add up to a compelling picture of capitalist crisis today – that's why the seemingly abstract questions of epistemology and ontology have become oh so very practical in our disastrous conjuncture. The very constructs we have used to discern the present, disastrous state of affairs – the Nature/Society divide – have outlived their usefulness. That dualism runs a knife through the web of real connections between human and extra-human natures that are fundamental to an emancipatory politics of life-making in the coming century.

Consider the ongoing dialogue over the Sixth Extinction of planetary life. Scholars, somewhat antiseptically, call this 'de-faunation'. In this important discussion, Nature/Society threatens to short-circuit a radical analytical imagination, one that would join the extinction of species with the accumulation of capital. A world-ecological account, as Tony Weis shows, begins with such connections. Here de-faunation appears as the flip side of

commodi-faunation. The acceleration of ecocide and the take-off of the meat-industrial revolution since the 1970s are, in such a frame, no mere coincidence. They are joined in the *fundamental* relations of capital, power and nature that make the modern world what it is. Such an alternative follows the really decisive relations of capitalist crisis-generation, from the biosphere to animal and human bodies to the capitalist transformation of landscapes. In Weis's powerful formulation, we are able to follow the world-historical movements of 'ghosts' (extinguished species) and 'things' (commodified animals as meat). One part of this movement renders the necessary human labour-power and raw materials to the gates of meatpacking plants and factory farms. The other part simply exterminates life, carrying the law of value to its logical conclusion. Neither part of this crisis-generating complex can be reduced to its Social and Natural parts because every moment implicates specific bundles of human and extra-human nature.³

The limits to modernity are made through the web of life. Once a novel, even controversial, statement, that idea is now widely accepted. But it hasn't quite sunk in. Not really. The web of life today is still widely considered in its 1970s' incarnation: *natural* limits. The very core of capitalist development is premised on a dialectical movement that simultaneously globalizes our daily lives and our relations to planetary nature, not only creating successive opportunities for capital accumulation, but persistently undermining the real basis of accumulation: the Cheap Natures of food, labour-power, energy and raw materials. As Marx and Engels understood, 'natural' conditions are not so natural as we might think.

There *are* limits. But limits to what? A quarter-century ago, Ted Benton rightly observed that every civilization is a 'specific structure of natural/social articulation' with *specific* limits to the reproduction of that articulation.⁴ Radicals have focused on the first part of that observation – 'natural/social'. But we find the heart of the matter in that last word: *articulation*. Once we start to look at the relationality of power and re/production in the web of life, we move beyond dualism; it begins to dissolve.

If limits are found in the relations of power and re/production, bundled with specific historical natures, then our thinking about crisis begins to shift. A limit for one civilization is not necessarily a limit for another. Civilizations – call them historical systems or modes of production if you wish – are ways of organizing the relations of human and extra-human natures. The putatively social relations of territorial

power, surplus production and accumulation, hegemonic cultures – all can be seen as bundled relations within specific historical natures. And the relations of ‘social reproduction’ are at once revealed as central to a civilization’s power/production relations *and* as transcendent of any Nature/Society dualism. (If someone can show me where the ‘social’ moment of child-rearing ends, and the ‘natural moment’ begins, please enlighten me.) In medieval Europe, this was parcellized sovereignty, the lord–peasant relation, and land productivity. In historical capitalism, this is the interstate system, bourgeois and proletarian, and labour productivity. These relations we call social, which they are in an expansive sense: they are relations of sociality and cooperation within the web of life. And they are relations co-produced with and within the web of life – yes, capitalism makes environments; yes, the web of life makes capitalism. Here is our double internality at work. Each moment internalizes the other, but never equally. Limits for one civilization take shape out of the very innovations – and evolving eco-geographical conditions – that allowed for its initial expansion. Capitalism, born of the prodigious and violent effort to produce Cheap Nature through global expansion, now finds itself limited by the same Cheap Nature strategies that allowed it to thrive for the past five centuries.

How do we go about sustaining a global conversation that would synthesize – theoretically, but one hopes also politically – a unified theory of capitalist crisis in the web of life? The question finds some traction – but also opposition – among a growing layer of the world’s Left, supported by a broad consensus around ‘converging’ crises.⁵ The ‘ecological’ and the ‘economic’ are, we are told, *converging*. But such a view presupposes that these moments were once separated. Hence the underlying uncertainty at the core of the consensus: the ongoing, cascading and impending tipping points of capitalism and the biosphere interact with each other – *somehow*.

But *how*? That’s a question with surprisingly few answers. What would such a synthesis look like? Let me outline the beginning of a more fruitful approach.

Crisis

Everyone knows why capitalism runs itself into crisis, right? Too many commodities chasing too few customers. Economists call this the problem of ‘effective demand’. For Marxists, the emphasis lies squarely within production and investment: overproduction and overaccumulation. For both, the problem of crisis

unfolds within the zone of commodification. My argument says something different: the problem of crisis unfolds through the unifying relations between the zone of commodification and the zone of reproduction, which is partly inside but largely outside the immediate circuit of capital. The tendency of surplus capital to rise, and of the world-ecological surplus to fall, are entwined.

We may begin with the basics. Capitalism is a system of endless accumulation. Because accumulated capital flows into the hands of a few (*capitalists*), a problem presents itself. Marx called this the ‘general law of capitalist accumulation’: riches for the few, poverty for the many. At some point, the goods and services produced in the ‘real economy’ cannot be purchased in a rising volume by those in ‘real life’. In one sense, this is an *overproduction* problem: too many factories produce too many cars, or refrigerators or computers that cannot be purchased in sufficient volumes to maintain the rate of profit. In another sense, it is an *overaccumulation* problem: the rate of profit in existing investment lines begins to fall, and new, more profitable investment opportunities have not emerged.

So far, so good. What has happened – in both radical and mainstream economic thinking – is a curious conflation of overaccumulation and overproduction. Why this should be so is no mystery. The formation of Marxist and neoclassical thought across the long twentieth century occurred during the long fossil-fuel boom. That boom made possible a series of innovations and transformations that propelled rising labour productivity, new agricultural and resource frontiers, and the radical extension of value relations worldwide, setting hundreds of millions of peasants ‘free’ to work for wages. It seemed to abolish the spectre of crisis haunting early capitalism: underproduction. Thus overproduction was the necessary and immediate problem that needed to be explained. And it became very easy to conflate overproduction with overaccumulation.

It was especially easy to conflate the two if one assumed that capitalism begins around 1800. This is what I call the ‘Two Century Model’. As I’ve explored elsewhere, this view has obscured the revolutionary shift in environment-making that occurred after 1450.⁶ Early capitalism was indeed real capitalism in every major respect: labour productivity increased, commodification widened and deepened with no systemic reversals, proletarianization accelerated sharply, capital moved into production, from farming to heavy industry, and a new scale, scope and speed

of environment-making altered regional ecologies across the planet.

Early capitalism's dominant crisis tendency was not overproduction, but *underproduction* – the insufficient flow of labour, food, energy and materials relative to the demands of value production. Early capitalism's greatest problem centred on the delivery of cheap inputs to the factory gates, not on selling the commodities that issued from manufacturing centres. To be clear, we are dealing with configurational weight: underproduction and overproduction always operate simultaneously. The Dutch Republic was the seventeenth century's 'model capitalist nation' (Marx) because it organized and led a world-ecological regime that delivered cheap grain (from Poland), cheap energy (from domestic peat) and cheap timber (from Norway and the Baltic) to the northern Netherlands. When this regime faltered, definitively by the 1760s, the British married technical ingenuity with geological good fortune to move from increasingly expensive wood fuel to increasingly cheap coal. This marriage solved – but did not abolish – the problem of underproduction, setting the stage for two centuries of remarkable expansion.

Marx's general law of underproduction

Marx did not like to write about scarcity. Malthus ruined the question for him. But it's not true that Marx avoided the problem. Arguably, Marx's general model of accumulation crisis is grounded in capital's co-production of value. The organic composition of capital, writes Perelman with some exaggeration, was 'a code for scarcity... In the back of Marx's mind, [capitalism's co-production of] scarcity was [partly] responsible for the falling rate of profit.'⁷

Scarcity probably isn't the best word for what we have seen in the history of capitalism. I'm with Marx on this – there is a better conceptual language we can use. Marx's choice was 'underproduction'. And among Marx's many 'general laws' the least appreciated is the general law of *underproduction*. In this, Marx identifies the circuit of capital as a socio-ecological relation, albeit one whose substance (value) is necessarily blind to 'natural distinctness'. In this model, 'the rate of profit is inversely proportional to the value of the raw materials': the cheaper the raw materials and energy, the higher the rate of profit. Why? Because 'constant' capital comprises two moments. One is fixed capital, comprising machinery, but also other extra-human forces of production, including animals, that outlast the production cycle. The other is *circulating* capital, not to be confused with the *circulation* (and circuit) of

capital. Circulating capital is the forgotten moment in Marx's model – a casualty of dualist habits of thought and a legacy of the fossil boom's intellectual footprint. It consists of energy and raw materials used up during a production cycle. The dynamism of capitalist production, observes Marx, leads the 'portion of constant capital that consists of fixed capital ... [to] run significantly ahead of the portion consisting of organic raw materials, so that the demand for these raw materials grows more rapidly than their supply.' Marx goes still further. Not only does fixed capital in industrial production tend to 'run ahead' of raw materials sectors; the *condition* for large-scale industrial production is Cheap Nature – 'it was only the large fall in the price of cotton which enabled the cotton industry to develop in the way that it did.'⁸ In sum: the 'overproduction' of machinery (fixed capital) finds its dialectical antagonism in the 'underproduction' of raw materials (circulating capital). This law, like the tendency of the rate of profit to fall, is a dialectic of tendencies and counter-tendencies, in which the latter are *endogenous*. This endogeneity of nature – through the double internality – sets Marx's perspective as a clear contrast to the Malthusian programme.

The issue is therefore not overproduction or underproduction. It is how the two *fit together* in successive eras of accumulation. Underproduction is of course much more than the overproduction of machinery and the underproduction of inputs. The model is too simple. We cannot, however, get to the complexities without it. The overproduction of machinery and the underproduction of raw materials is where long cycles of accumulation end up: rising raw materials prices and overcapacity. If there is nothing particularly revolutionary in the observation, it points us in two promising directions. The first is how the 'normal' accumulation of capital drives the rising costs of production through the progressive exhaustion of the natures within both the circuit of capital (exploitation) and in the orbit of capitalist power (appropriation). The second is how underproduction fetters – or threatens to fetter – accumulation, and how it has been resolved through great waves of geographical restructuring. Thus, eras that mark the demise of one long wave of accumulation and the rise of another tend to be accompanied by 'new' imperialisms and 'new' scientific revolutions. In these periods, capitalist and territorialist agencies seek to find, secure and appropriate Cheap Natures that can resolve the problems of the old order.

How do we go about unifying overproduction and underproduction in our model of accumulation?

The tendency of the ecological surplus to fall

This is a vexing question. Capital engages the world as something to be reduced to an interchangeable part. These reductions are at once symbolic and material. They comprise market-, class- and state-led simplifications. Crucially, the tendential generalization of value relations works through a dialectic of capitalizing production and appropriating reproduction. Value is encoded simultaneously through the *exploitation* of labour-power in commodity production, and through the *appropriation* of nature's life-making capacities. *Accumulation by appropriation* involves those extra-economic processes – perhaps directly coercive, but also cultural and calculative – through which capital gains access to minimally or non-commodified natures for free, or as close to free as it can get. If appropriation is partly about primitive accumulation, it is equally about the cultural hegemonies and scientific-technical repertoires that allow for unpaid work/energy to be mobilized, on a sustained but not sustainable basis, for capital accumulation. Such accumulation proceeds vigorously when unpaid work/energy is appropriated in service to commodity production, and opens new opportunities for capital investment. This occurs through geographical expansion, and is most effective when empires and states do the hard work of imposing order – cultural, scientific, juridical and the rest – on new spaces. Such geographical expansion, in other words, must involve capitalist power and rationality in rather heavier doses than capitalization itself. Appropriation works through projects to control, rationalize and channel potentially unruly human and extra-human sources of unpaid work/energy, *without immediately capitalizing these sources*.

Capitalization can and does occur. But it must be kept in check. If accumulation is to revive, capitalization must serve the 'greater good' of appropriation. When capitalists can set in motion *small* amounts of capital and appropriate *large* volumes of unpaid work/energy, the costs of production fall and the rate of profit rises. In these situations, there is a high world-ecological surplus (or simply 'ecological surplus'). This ecological surplus is the ratio of the system-wide mass of capital to the system-wide appropriation of unpaid work/energy. In this, the 'mass of capital' involves not only fixed capital but also relations of human and extra-human reproduction that are increasingly capitalized: labour-power, tree plantations, factory farms, and so forth.

The ecological surplus is suggested, albeit too narrowly, by the EROI ratio – energy returned on energy

invested – pioneered by ecological economists. Its decline is suggested by the declining energy efficiency of industrial agriculture, a long-time staple of Green critique. This orients us to the centrality of unpaid work/energy in the rise and demise of successive accumulation cycles. EROI becomes useful in analysing capitalism's crisis, however, only when we move towards EROCI: energy returned on *capital* invested. EROCI's decline is suggested by mounting evidence of rising production costs and slowing labour productivity growth over the past two decades – in agriculture, extraction and industry. That decline suggests a powerful question: has capitalism entered a new era of secular decline in the ecological surplus, and therefore in its capacity to achieve a significant advance in system-wide labour productivity?

Historically, 'great depressions' have been resolved through world-ecological revolutions that create opportunities for windfall profits. These new opportunities depend upon the restoration of the Four Cheaps – labour-power, food, energy and raw materials. These Cheaps form the core of the world-ecological surplus. It is a 'surplus' relative to the average costs of production in capitalism, which take many forms but are ultimately rooted in the productivity of labour. Such productivity is, however, decisively linked to the production of new historical natures and their chief historical forms: successive waves of enclosure, imperial expansion, scientific practice and dispossessionary movements. These combine with technical change to appropriate unpaid work/energy faster than the tendentially rising capitalization of global nature.

When the ecological surplus is very high, as it was after World War II, productivity revolutions occur and long expansions commence. Naturally, this is not merely a story of appropriation, but also of capitalization and socio-technical innovation. The ecological surplus emerges as new accumulation regimes combine plunder and productivity, joining the enclosure of new geographical frontiers (including subterranean resources) and new scientific-technological revolutions in labour productivity. Great advances in labour productivity, expressing the rising material throughput of an average hour of work, have been possible through these great expansions of the ecological surplus. The assembly line of classic Fordism, for instance, was unthinkable without cheap steel, rubber and oil. It is impossible to overstate the irreducibly socio-ecological character of this surplus, which comprises not only food, energy and raw materials, but also human nature as

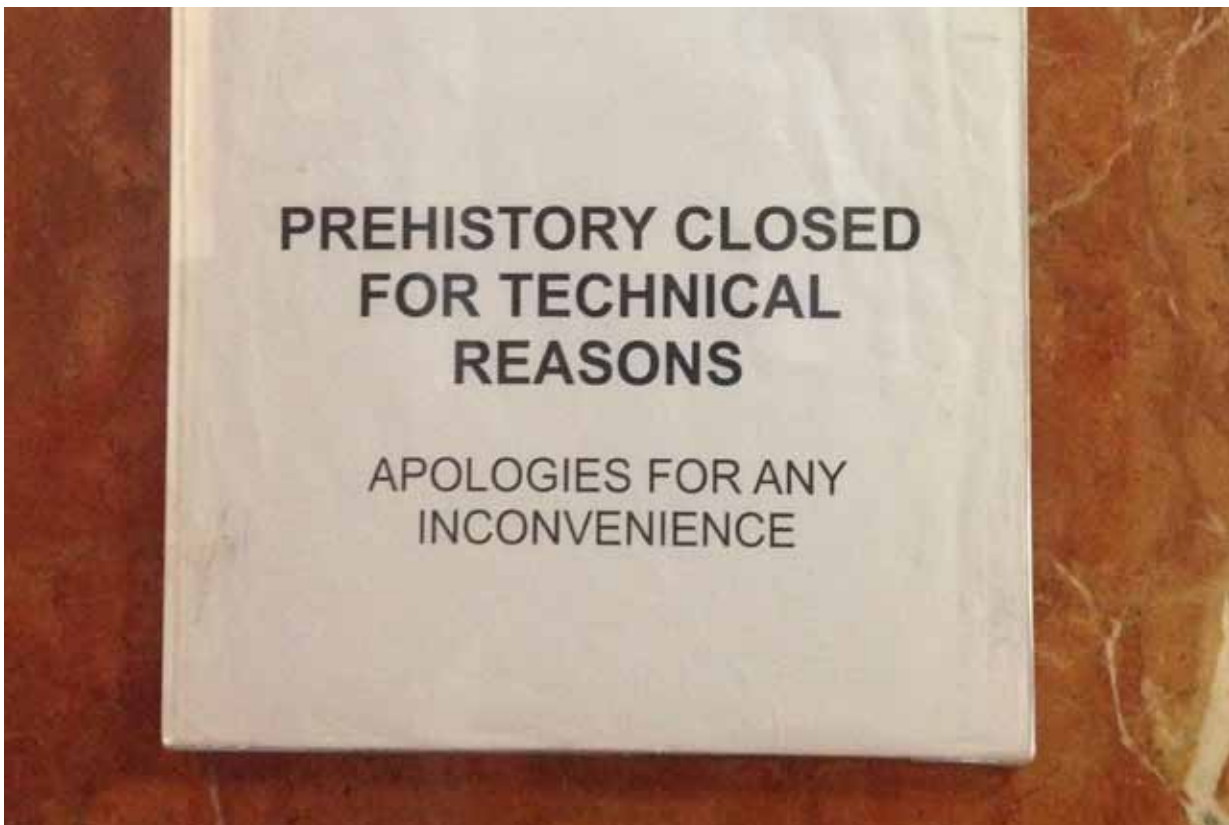
labour-power and domestic labour. The origins of the long twentieth century were found not only in the mass production systems of the 'second industrial revolution', but also in multiple appropriations of human and extra-human natures: of the soil and water resources of the American Midwest; of eastern European and South Asian peasantries; of the forests, fields and resource veins of the colonial and semi-colonial worlds.

The ecological surplus declines over the course of every long wave of accumulation. It falls for four big reasons. First, there is wear and tear on the *oikeios* – on the specific historical natures in play. This is an entropy problem: matter/energy move from more useful to less useful forms within the prevailing configuration of the *oikeios*. The 'law of entropy' – whereby 'all economic process[es] ... transform valuable matter and energy into waste'⁹ – operates within specific patterns of power and production. It is not determined by the biosphere in the abstract. From the standpoint of historical nature, entropy is reversible and cyclical – but subject to rising entropy within specific civilizational logics. Capitalism's logic of appropriating work/energy therefore allows recurrent fixes to rising entropy by locating uncaptured natures on the frontier.

Second, even if there was *no* wear and tear, the ecological surplus would tend to decline. The mass

of accumulated capital tends to rise faster than the appropriation of unpaid work/energy – a necessary implication of Marx's general law of underproduction. (Capital's bets on the future grow faster than the practical activity of locating new Cheap Natures.) Even in the exceptional circumstances of the 'second' industrial revolution and the post-World War II golden age – when the appropriation of unpaid work/energy was at an all-time high – the cheapening of food, raw materials and energy required extraordinary effort and was sometimes reversed. The cyclical movement towards rising costs, like the entropy problem, can be reversed, but the space for such reversals narrows over capitalism's *longue durée*. In this light, Marx's general law of underproduction may be formulated as a tendency for the rate of accumulation to decline as the mass of capitalized nature rises. It finds historical expression in recurrent waves of financialization, the chief expression of the overaccumulated capital that piles up as opportunities for appropriation decline.

Third, the ecological surplus declines through the contradiction between the reproduction time of capital and the reproduction times of the rest of nature. Capital's dystopian drive towards temporal instantaneity manifests itself by finding 'short cuts' to compress the reproduction times of manifold natures. Not all human-initiated compressions are violent; but nearly all of capitalism's are. Capitalist agriculture,



with its monocultures and labour productivity fetish, is a prime example. The capitalization of nature proceeds because this confers a competitive advantage over the short run. Capitalizing nature yields short-run gains for particular capitalists, but middle-run costs. These costs are externalized wherever possible, but ultimately new sources of work/energy must be found, and appropriated. Thus every long accumulation cycle unfolds through new commodity frontiers.

Finally, the share of unpaid work/energy tends to fall relative to the mass of capital not only because of entropy, capitalization and temporal disproportionality, but also because the accumulation of capital becomes more wasteful over time. This dimension is cyclical, but the least cyclically problematic. (Until now.) It is arguably the most cumulatively significant. One form is the colossal energy inefficiency of industrial agriculture. Another, epoch-making dimension of waste production concerns the ways that massive energy and chemical use is now toxifying the biosphere, and activating *negative-value*: the emergence of historical natures that are increasingly hostile to capital accumulation, and that can be temporarily fixed (if at all) only through increasingly costly and toxic strategies. The rise of negative-value – expressed starkly in contemporary climate change – suggests a significant and rapid erosion of the ecological surplus in the early twenty-first century.

This means that capital, over time, must pay a greater share of its costs of doing business. In formal terms, every great wave of accumulation begins with a high ecological surplus, which is created through combinations of capital, science and power.¹⁰ We may associate these moments with abstract social labour, abstract social nature, and primitive accumulation. This triple helix of accumulation works by developing new ways of advancing labour productivity, alongside the securing of new and greatly expanded sources of unpaid work in service to accumulation. This is the dialectical counterpoint to the traditional rendering of Marx's so-called primitive accumulation as a process of class formation (bourgeois and proletarian). Class formation is one result of primitive accumulation. This result depends upon, and is co-produced through, the appropriation of unpaid work by 'women, nature and colonies'. But the processes of identifying, mapping and rationalizing those new sources of unpaid work/energy cannot be explained by economic forces alone; they depend upon state and science to make them work. Thus, primitive accumulation and the geographical expansion of capitalism are about more than the transfer of wealth from

the non-capitalist to the capitalist world. And they are about more than the relation of bourgeois and proletarian. *Primitive accumulation is equally about the restructuring of the relations of reproduction – human and extra-human alike – so as to allow the renewed and expanded flow of cheap labour, food, energy and raw materials into the commodity system.*

The dialectic of capitalization and appropriation

Let us now consider capitalization and appropriation not merely as accumulation strategies but as relations of reproduction. From there we may consider the relations between the two. First, the capitalization of relations of reproduction has occurred most conspicuously through the proletarianization of human labour. 'Proletarianization' is another way of saying that the reproduction of labour-power flows through capital, largely in the form of paid work. Of course, even proletarian households in the global North continue to rely upon significant expenditures of unpaid work (laundry, cooking, raising children, etc.). Humans transform the rest of nature only through work, and the commodification of work – directly and indirectly – is therefore pivotal to the capitalization of extra-human natures.

But it is not just the reproduction of labour-power that has become capitalized; it is also the reproduction of extra-human natures. Flows of nutrients, flows of humans, and flows of capital make a historical totality, in which each flow implies the other. Modern agriculture, from its genesis in the sugar plantations of the long sixteenth century, reveals cash-crop agroecologies as a process of appropriating nutrients, energy and water through global capital flows, credit especially. The extraordinary shift that occurred in the twentieth century – through successive hybridization, chemical and biotechnological 'revolutions' – has been the rising capitalization of nature. But it has been non-linear, and consequently obscured until recently, because of the radical cheapening of energy. Nitrogen-fixation was of course central, but so were mechanization, pesticides and electrification. The liberation of capitalist agriculture from its dependence on local energy sources significantly *reduced* capitalization for a quarter-century after World War II – and modestly after the 1970s. Recently, however, this process has boomeranged, significantly *advancing* capitalization over the past decade. At some point, every agricultural revolution faces a 'blowback': from human-centred revolts to extra-human resistance (e.g. 'superweeds'). The dynamic is captured, albeit

partially, in discussions of capitalist agriculture's 'technological treadmill', as farmers are locked into a regime of rising costs through dependence on commodified seeds, machines and poisons. But the 'treadmill' expands beyond the forces of production. It is a treadmill of capital, tools and nature – the *technics* of agro-industrial capitalism. The farm family must strive to produce more and yet more to satisfy the debt obligations of an agro-ecological model whose reproduction flows primarily through the circuit of capital. The capitalization of agriculture today – in contrast to a century ago – is now exceeding cash-crop agriculture's appropriation of unpaid work/energy, a reality indicated by industrial agriculture's three decades of declining productivity growth. The ecological surplus is contracting.

Capitalization transcends the 'Cartesian' binary. So too does the appropriation of unpaid work/energy. This dialectic allows us to see beyond the reductionist language of Society and Nature. For in capitalism, the crucial divide is *not* between Society and Nature – it is between capitalization and the web of life. Capitalism's arrogance is to assign value to life-activity within the commodity system (and an alienating value at that) while devaluing, and simultaneously drawing its lifeblood from, uncommodified life-activity within reach of capitalist power.

These movements of capitalization and appropriation mutually determine socially necessary labour-time. The first movement occurs within Marx's 'organic whole' of commodity production, comprising distribution, exchange, alongside immediate production. The other is the 'organic whole' of appropriating unpaid work in service to advancing labour productivity. In other words, the rate of exploitation under the law of value is determined not only by the class struggle within commodity production (between capitalist and the direct producers), and not only by the organization and value composition of commodity production. *It is also determined by the contribution of unpaid work* – work reproduced largely outside the circuit of capital – performed by human and extra-human natures alike.

The appropriation of unpaid work – manifested in the cyclical rise and decline of the Four Cheaps – is consequently central to conceptualizing and investigating capitalism's limits. This is because the *real historical limits* of capitalism derive from capital as a relation of capitalization and appropriation. The 'limits to growth' are not external, but derive from relations internal to capitalism. Why internal? Clearly, we are not speaking of 'internal' as a fixed

boundary, but rather of capitalism as an *internalizing* civilization. We are speaking of *internal* as methodological premiss, not descriptive statement. Ecological economists often speak of how capitalism 'externalizes' costs. The conversion of the atmosphere to a dumping ground for greenhouse gases is a prime example. Such externalization of costs is also the internalization of spaces necessary for capital accumulation. The atmosphere, for instance, must be put to work as capital's unpaid garbage man. These spaces may or may not be *directly* within the circuit of capital. Such spaces may be oilfields (internal to capital) or they may be frontier zones, where waste is dumped, or unpaid work appropriated. While waste frontiers are now partially recognized, the internalizing character of capitalist civilization goes still further, precisely because the accumulation of capital depends upon the active incorporation of 'physically uncorrupted' sources of work/energy.¹¹

This inverts the usual thinking about capitalist development. Capitalism expands *not* to expand the domain of commodification as such; it expands to shift the balance of world accumulation towards appropriation. Thus capitalism's geographical expansions only sometimes – and only partially – privilege commodification. Most often, the priority is the projection of capitalist power into uncapitalized domains of reproduction: of uncommodified human and extra-human natures. These latter have been continually invaded, penetrated and subsumed by capital, but always only ever partially – and for a good reason. Great advances in labour productivity – the British-led Industrial Revolution and American-led Fordism in the long nineteenth and twentieth centuries – have been strongly conditioned on gigantic appropriations of *unpaid* work, performed by human natures (domestic labour) and extra-human natures (geological accumulations) alike. Such industrializations depend on a configuration of rising labour productivity (rate of exploitation) in commodity production, alongside a *disproportionately greater* appropriation of unpaid work. The implication is crucial and merits emphasis: *the relation between exploitation and appropriation is asymmetrical*. Rising labour productivity in commodity production implies an even greater augmentation of the volume of energy and raw materials (circulating capital) for every unit of labour-time. Accumulated unpaid work/energy is especially important. The British- and American-led industrial revolutions, for example, unfolded through epoch-making appropriations of the accumulated work/energy of fossil fuel formation (coal, then oil)

and the accumulated work/energy of humans raised to adulthood outside the commodity system (dispossessed peasants).

This highlights the historical unity of the reproduction of human and extra-human natures. From this perspective, *work* encompasses much more than direct participation in commodity production. Rather, work encompasses the totality of waged and unwaged activity performed by humans and the rest of nature within reach of capitalist power. The *unpaid* 'work of nature' – over the short run of agriculture, the inter-generational time of child-rearing, the geological time of fossil-fuel creation – is the pedestal upon which the *paid* 'work of capital' unfolds. Both moments are inscribed in the law of value. While the value form (the commodity) emerges in the immediate process of production, the value relation – *including the systemic determination of socially necessary labour-time* – encompasses not only production relations, but also the broader relations of appropriation necessary to the expanded production of surplus value. The rate of exploitation is fundamentally conditioned by the scale, speed and scope of appropriation of nature's work/energy, provided 'free of charge', or as close to free as possible.

As the Four Cheaps materialize, new opportunities for capital accumulation appear: for instance, the railroad revolution of the nineteenth century or the automobile revolution of the twentieth century. Over time, the Four Cheaps cease being Cheap. The squeezing out of unpaid work/energy in the upswing of an accumulation cycle exhausts the resilience of uncommodified relations of reproduction. Meanwhile, workers and peasants find new ways to contest capital and the world market. Labour and input costs rise, and the rate of profit in established lines of production falters. This is when financial expansions – a recurrent feature of capitalism from the sixteenth century – commence. As leading states feel the pinch, they set to work restructuring their relations of power and re/production within historical nature. Thus do financial expansions inaugurate new eras of primitive accumulation, as capitalists and states pursue the restoration of Cheap Nature.

Haunting capital's productive dynamism is the spectre of underproduction. There is, consequently, a strong impulse to dissolve the boundaries between the Big Four inputs: to turn food into energy and raw materials, energy into food, and of course energy into labour-power. Here is capital's project to create Nature in its own image, endlessly quantifiable and interchangeable. One moment of this

project is directly bio-material. Maize is a paradigm case, leading the way for all manner of 'flex crops'. It provides the raw materials for, seemingly, just about everything: ethanol, food and raw materials in construction and industrial production. Another moment is the generalization of energy-intensive nitrogen fertilizers in world agriculture, compelling a growing share of humanity to 'eat' fossil fuels. And let us not forget that capitalism is premised on the dissolution of human specificity – craft knowledge and the like – that is embodied in the incessant drive to replace 'living' with 'dead' labour.

The movement towards the increasing fungibility of extra-human nature is also calculative. The financialization of commodities since the turn of the millennium is another key moment in this dissolution of the boundaries between the Big Four inputs. Perhaps most spectacular is the recent history of global primary commodity markets. Before the twenty-first century, these were largely independent 'from outside financial markets and from each other' – for example, the price of oil was not necessarily correlated with the price of copper. After 2000, however, financial actors, index investors especially, 'precipitated a fundamental process of financialization among commodities markets, through which commodity prices became more correlated with prices of financial assets and with each other.... As a result of [this] financialization ... *the price of an individual commodity is no longer simply determined by its supply and demand.*'¹² This combination of bio-material and financial restructuring suggests a twenty-first-century scenario in which the tendency towards underproduction reasserts itself, through an unusual and unstable combination of physical depletion, climate change, new anti-systemic movements and financialization.

Underproduction signifies a *conjoncture* – the downslope of a bell-shaped curve – in which one or more of the Big Four inputs becomes increasingly costly, and begins to fetter the accumulation process. In this, underproduction is an immanent contradiction of overproduction. This means that underproduction is not about 'scarcities' that reside in an external nature – a neo-Malthusian view. Rather, underproduction takes shape through the relations that obtain, cyclically and cumulatively, in historical capitalism and historical nature (our double internality). Underproduction is co-produced by human and extra-human natures, and historically specific. 'Scarcity' for one civilization may not be for another. Capitalism's scarcities are imposed through

price – the food price inflation that began in 2003 is not a function of inadequate world food supplies, but of distribution, power and capital. This allows us to see the *really relational* sources of hunger and other forms of deprivation and oppression. But the analysis cannot stop there. We need a way to see how changes in the biosphere translate into deepening contradictions in capitalism – and vice versa.

Peak appropriation

Depletion is real enough. Its most salient contemporary expression is probably energy. Here, the geographical retreat of easy-to-extract big oilfields is clearly a contest over the terms of the double internality. Will capitalism's internalization of nature produce new geographies that allow for Cheap Energy's return? Or will nature's internalization of capital produce new geographies that make such a return impossible? We have been distracted from this double internality by the terms of the 'peak everything' debate. These terms pose a question about substances, not relations: have we reached a 'peak' in global output for oil, coal, phosphorous, even soil, from which a 'post-peak' world of scarcity ensues?

What happens if we approach the problem of depletion from a world-ecological perspective? Here we find more useful a different kind of peak: *peak appropriation*. Peak appropriation may be visualized as the maximal inflection point of a bell-shaped curve in which the share of unpaid work/energy peaks relative to the capitalization of nature: that 'peak' represents the world-ecological surplus at its highest point. Of course the visualization is merely a thought exercise. Cyclical changes and sectoral shifts alter the picture in significant ways. Since the early nineteenth century, moreover, the relative ease with which Cheap Energy could be mapped, extracted and put to work has smoothed the transition from one phase of capitalism to another.

Peak appropriation is one way of building on EROI (energy returned on energy invested) analyses. It allows for the enfolding of resource and energy measures in a historical and relational frame. The movement towards peak appropriation, as we've noted, sees a rising ecological surplus. Post-peak appropriation is characterized by a falling ecological surplus. But EROI cannot get us to a model of accumulation that unifies energy/capital.

Appropriation and the cyclical movements of the ecological surplus direct our attention not only to EROI but to *Energy Returned on Capital Invested*

(EROCI): calories or joules per dollar. EROCI puts the relative contributions of paid and unpaid work/energy at the centre. The *peak* in question is not, then, a peak in output – of energy, or some other primary commodity. It is, rather, the peak 'gap' between the capital set in motion to produce a given commodity and the work/energy embodied in that commodity: dollars per bushel, or ton, or barrel, or horse, or hour of labour-power. Even here, the language is imprecise, because we are dealing with an incommensurable mix of specific work/energies. Quantification can illuminate but not adequately capture these specifics. Energy and material flows can be measured; but within capitalism they cannot be *counted* – for the secret of capital's dynamism is that it counts only what it values (labour productivity). Peak appropriation is, moreover, not simply about particular commodities, but about the ways that certain primary commodities – coal and oil are paradigm examples – 'diffuse' Cheap Natures across the whole accumulation process. Cheap Food after the 1930s, for instance, became 'petro-farming', its prodigious appropriations of soil, water and life increasingly mediated through Cheap Energy.

For long waves of capital accumulation, peak appropriation occurs when the contribution of appropriated natures 'peaks' relative to capitalized natures. Hence Marx's insight on soil fertility as 'fixed capital'. Of course Marx understood fertility as not so natural (fixed) as Ricardo believed; fertility could be increased through the application of fertilizers as circulating capital.¹³ But where fertility was given, prior to the advance of capitalist agriculture, the windfalls of peak appropriation could be epoch-making. The American grain frontiers of the nineteenth century appropriated nutrients accumulated over millennia. When combined with the capital-intensive family farm, they revolutionized not only American capitalism but also flooded Europe with Cheap Food, 'freeing' Cheap Labour for American industrialization. As with early capitalism's sugar plantations, we see the precocious combination of cutting-edge industrial production and frontier appropriation. The potential consequences of rising capital-intensity – rising production costs – could be offset through new appropriations and enclosures. The radical acceleration of appropriation was expressed in all manner of enclosures, colonial and metropolitan, new and old. These allowed capital to advance labour productivity while reducing (or checking) the tendentially rising value composition of production. The technical composition of production – the mass of machinery and

raw materials relative to labour-power – could rise without undermining the rate of profit.

The final frontier

At the core of the capitalist project, from its sixteenth century origins, has been the scientific and symbolic creation of nature in its modern form, as something that could be mapped, abstracted, quantified and otherwise subjected to linear control. This was external nature; it is what we have come to call Nature, even if many of us no longer believe in a Nature that is independent of the Anthropos. (And is not the Anthropos as violent an abstraction as Nature?) It is easy to talk about the ‘limits to growth’ as if they were imposed by this (external) Nature. But the reality is thornier, more complex – and also more hopeful. The limits of capitalist civilization include biophysical realities, but are not reducible to them. And if the limits of capitalism today are limits of a particular way of organizing nature, we are confronted with the possibility of changing humanity’s relation to nature – which is to say also humanity’s relation to itself. We are frequently warned of the alleged dangers of civilizational ‘collapse’. But is the ‘collapse’ of capitalism – a civilization that plunges a third of its population into malnutrition – really something to be feared? Historical experience suggests not. The Fall of Rome after the fifth century, and the collapse of feudal power in Western Europe in the fourteenth century, ushered in golden ages in living standards for the vast majority.¹⁴ We should be wary of making too much of such parallels. Neither should we ignore them.

I have long thought that the most pessimistic view is one that hopes for the survival of modernity in something like its present form. But this is impossible, because capitalism’s metabolism is inherently an open-flow system that continually exhausts its sources of nourishment. There are limits to how much new work capitalism can squeeze out of new working classes, forests, aquifers, oilfields, coal seams and everything else. Nature is finite. Capital is premised on the infinite. And both are *historical* in a very specific sense: what worked at one historical juncture will not necessarily work at the next. Thus the centrality of frontiers in the history of capitalism, and the significance of the *end* of the last frontiers – cheap oil in the Middle East, cheap labour-power in China, cheap food everywhere – in the present conjuncture. It was capitalism as frontier that inaugurated a civilizational metabolism in which most nature, including most humans, was

sacrificed in service to the productivity of wage-labour. These frontiers of appropriation were the major way of making others, outside the circuit of capital but within reach of capitalist power, foot the bill for the endless accumulation of capital. The great secret and the great accomplishment of capitalist civilization have been to *not* pay its bills. Frontiers made that possible. Their closure is the end of Cheap Nature – and with it the end of capitalism’s free ride.

Notes

1. Key texts in the world-ecology conversation include Jason W. Moore, *Capitalism in the Web of Life*, Verso, London, 2015; Tony Weis, *The Ecological Hoofprint*, Zed Books, London, 2013; Christian Parenti, ‘The Environment Making State’, *Antipode*, 2014 (early view version); Sharae Deckard, ‘Mapping the World-Ecology’, *Ecologies Technics & Civilizations*, forthcoming; Michael Niblett, ‘World-Economy, World-Ecology, World Literature’, *Green Letters*, vol. 16, no. 1, 2012, pp. 15–30; Benjamin Marley, ‘The Coal Crisis in Appalachia’, *Journal of Agrarian Change*, 2015 (early view version); Roberto José Ortiz, ‘Latin American Agro-Industrialization, Petrodollar Recycling, and the Transformation of World Capitalism in the Long 1970s’, *Critical Sociology*, 2014 (online first).
2. Quotations, respectively, from Karl Marx, *Critique of Hegel’s ‘Philosophy of Right’*, trans. Annette Jolin and Joseph O’Malley, Cambridge University Press, Cambridge, 1970, p. 137; H. Maturana and F. Varela, *The Tree of Knowledge*, Shambhala Press, Berkeley CA, 1987, p. 25.
3. Rodolfo Dirzo et al. ‘Defaunation in the Anthropocene’, *Science* 345, 2014, pp. 401–6. See also Weis, *Ecological Hoofprint*; ‘Ghosts and Things: Animal Life in the Capitalocene’, paper presented to the conference ‘World Society, Planetary Natures’, Binghamton University 8–10 July 2015.
4. Ted Benton, ‘Marxism and Natural Limits’, *New Left Review* 1/178, 1989, pp. 51–86.
5. See, for example, S. George, ‘Converging Crises’, *Globalizations*, vol. 7, nos 1–2, 2010, pp. 17–22; J.B. Foster, ‘The Epochal Crisis’, *Monthly Review*, vol. 65, no. 5, 2013, pp. 1–12.
6. See especially Jason W. Moore, ‘The Capitalocene, Part I’, *Journal of Peasant Studies*, forthcoming.
7. M. Perelman, ‘Marx and Resource Scarcity’, in Ted Benton, ed., *The Greening of Marxism*, Guilford Press, New York, 2006, p. 73.
8. Karl Marx, *Capital*, Volume III, trans. Ernest Untermann, International Publishers, New York, 1967, pp. 111–19; *Grundrisse*, trans. Martin Nicolaus, Vintage, New York, 1973, p. 141; *Theories of Surplus Value*, Volume III, Progress Publishers, Moscow, 1971, p. 368.
9. N. Georgescu-Roegen, ‘Energy and Economic Myths’, *Southern Economic Journal*, vol. 41, no. 3, 1975, pp. 347–81.
10. These three categories – ‘science’ most of all – are tremendously blunt instruments.
11. Marx, *Capital*, Volume I, p. 380.
12. K. Tang and W. Xiong, ‘Index Investment and Financialization of Commodities’, working paper, Department of Economics, Princeton University, Princeton NJ, March 2011 (emphasis added); www.princeton.edu/~wxiong/papers/commodity.pdf; accessed 17 March 2011.
13. Marx, *Grundrisse*, p. 748; and Karl Marx, *The Poverty of Philosophy*, International Publishers, New York, 1963, pp. 162–3.
14. C. Wickham, *Framing the Middle Ages*, Oxford University Press, Oxford, 2005; Immanuel Wallerstein, *The Modern World-System I*, Academic Press, New York, 1974.