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An Ecological Perspective on Uneven Development

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Uneven Development as a Result of the Unequal Exchange of Time and Space: Some Conceptual Issues[1]

For almost three decades, I have attempted to understand the economic polarizations of global society in terms of asymmetric transfers of resources that are made invisible by the dominant ways of representing development, economic growth, and technological progress. The acknowledgement of such asymmetric transfers – referred to in this research as the 'thermodynamics of imperialism' or 'ecologically unequal exchange' (Hornborg 1992, 1998) – is fundamental to understanding not only development gaps, but the very phenomenon of 'technology' as a social redistribution of resources. In recent years, it has been encouraging to see an increasing number of researchers involved in defining and measuring different kinds of ecologically unequal exchange (cf. Jorgenson/Clark 2009), even if the implications of this work for a radical reconceptualization of 'technology' remain difficult for most to digest.

This paper continues to scrutinize the concept of unequal exchange, which is a cornerstone not only of Marxian social theory but also of much ecological and post-colonial critique of the notion of 'development'. Many social scientists, looking at the world around them, are intuitively convinced that there is such a thing as 'unequal exchange' but would admit to having a hard time defining it. The problem of 'unequal exchange' is a paradigmatically Marxian topic in that *our difficulties in conceptualizing it can be seen as part of the conditions for its existence*. Thus it cannot be understood other than through an analytically demanding combination of epistemological and ontological arguments that require at different steps in the analysis the approaches of both deconstruction and objectivism.

My previous attempts to conceptualize 'ecologically unequal exchange' (e.g., Hornborg 1992, 1998, 2001, 2009) have raised two related kinds of

objections to which a response is detailed here. The first is that the very notion of 'unequal' exchange must imply some kind of value judgement, and the second is that it should refer to the specific definition applied by Arghiri Emmanuel (1972). The following section aims to demonstrate why the first objection must be deemed invalid, by arguing that if objectively quantifiable net transfers of resources can be shown to be conducive to uneven capital accumulation (or 'development'), a normative concept of 'value' or 'inequality' is not required in order to observe that uneven development is a result of unequal exchange. The second objection is addressed in section 2.

1. How to define 'unequal exchange' without recourse to a normative theory of value

Few mainstream economists today would recognize the notion of 'unequal exchange' as an acceptable category of economics, but tend to deal with the problem of global inequalities by referring to monopolies and 'imperfect information'. The economists' solution is to try to envisage conditions for completely 'free' trade and more perfect competition and information flows, but if after two centuries the supposedly equalizing doctrines of free market economics continue to remain a distant mirage, it should be incumbent on economists to devise more realistic strategies to achieve equality. Suffice it to say here that as long as exchange is conducted in terms of monetary exchange values, and prices are understood to reflect the rational or even benevolent logic of market forces, there is no way – other than under conditions of monopoly – that a market transaction can be classified as 'unequal'. A million dollars' worth of Swedish Volvos exchanged for a million dollars' worth of Venezuelan oil is *by definition* perfectly 'equal' in terms of exchange value, which is the only gauge that neoclassical economic theory is capable of applying. However profoundly we manage to deconstruct the phenomenon of money as a vacuous, semiotic delusion, aptly classified by Marx as a species of 'fetishism', the ideological and practical hegemony of exchange value, gauged in terms of market prices, remains more intact than ever. The foundations of modern economics were devised by and *for* British bankers and stock traders in the

early 19th century, yet continue globally to pervade the lives and thoughts of dominator and dominated alike.

Initially influenced by the Physiocrats' conviction that land was the ultimate source of value (Gudeman 1986), David Ricardo later subscribed to a labor theory of value that also became fundamental to the ideas of Karl Marx. Marxian theory has from the very start struggled with the analytical problem of how to effectively challenge the mainstream trust in money and in the fairness of market logic. Marx suggested that the market price of labor did not do justice to its 'real' value. Although he and his followers would be the last to admit it, he thus offered what is arguably a *normative* theory of value in the sense that it defined 'value' not in terms of the actual, subjective valuations of market actors – as in the fundamentally descriptive, neoclassic notion of 'utility', reflected in prices – but in terms of an analytical construct (the labor theory of value) that itself proposed to define an *objective basis of value*. Rather than accepting 'value' as contingent on the aggregated and transient subjectivities of consumers, Marx's supremely justified struggle to uncover the material conditions of accumulation (and the obvious exploitation of the working class) thus led him to conceive an analytical oxymoron. Beyond the mystifying price tags on labor that we know as wages, he pursued an objective foundation of value. Following Ricardo, Marx believed that embodied labor value was systematically reflected in exchange value. But valuation is a subjective act, and to 'objectively' define value is (paradoxically) itself an act of valuation.

Although meant to serve a commendable political purpose in Marx' own time, this approach to 'value' must be rejected as analytically untenable. Marx realized that in order to challenge the market ideology legitimizing capital accumulation, e.g. by positing asymmetric transfers of 'surplus value', it would be necessary to acknowledge some other gauge than price, but unfortunately chose to conceive this other gauge in terms of 'value'. The mistake was to conceptualize material asymmetries in terms of a subjectivist terminology. The concept of 'value' is itself normative. I doubt that it will ever be possible to convince economists or market actors that academics have a better knowledge of the 'real' value of things than the majority of market actors themselves. So, what does this other gauge – labor – represent, if not value?

The answer may be easier to detect if we turn to another kind of normative theories of value, namely those that underneath the price tags recognize not primarily labor but more generally *energy*. There have been many proponents of such theories over the years, including the so-called Technocrats in the 1930s and, more recently, the ecologist Howard T. Odum (1988), the economist Robert Costanza (1980), and the sociologist Stephen Bunker (1985). Odum's notion of *eMergy* (or 'energy memory') echoes Marx in suggesting that the 'real' value of a commodity reflects the amount of energy that has been invested in its production. Like Marx, Odum used an ultimately normative theory of value to pursue a putatively *scientific* argument that exchange can be viewed as unequal in the sense that some social categories are not properly compensated (Odum/Arding 1991). Costanza (1980), on the other hand, traced empirical correlations between embodied energy and price, in effect offering a *descriptive* energy theory of value, without considering the possibility of unequal exchange resulting from discrepancies between prices/wages and energy 'value'.

What both 'labor' and 'energy' have in common is that they are measures of *productive potential*. They are literally the 'productive forces' of any production process. But, contrary to Marx and Odum, there is no specifiable relation between the amount of productive potential that has been invested in a commodity and the way it will be evaluated on the market. Rather than reduce economics to thermodynamics, our task should be to see how the two are related. We need to keep them analytically separate while showing how they are interfused in actual social processes.

We have no theoretical reason to posit a connection between the attractiveness of commodities and the volume of labor time (or any other biophysical metric) that has been invested in their production. The former is tantamount to 'value' (= exchange value = price), the latter one of several possible measures of embodied productive potential (also including e.g. energy, eco-productive land area, volume of materials, etc.), and there need not be any positive correlation between them. The so-called 'transformation problem' is thus a non-problem. 'Value' is what consumers desire. To claim that value is essentially a question of invested labor time (or energy, or land area, and so on) is itself a *valuation*, in other words, to confuse that which is to be explained with the theory purporting to explain it.

Rather than say that we as social or natural scientists have access to a more authentic measure of 'value' than the people who do the valuing, we here have reasons to agree with the mainstream economists that 'value' is defined by the cultural preferences of consumers. This agrees well with anthropological and sociological studies of the semiotics of consumption following the work of Jean Baudrillard (1972), Marshall Sahlins (1976), and Pierre Bourdieu (1984), who all argued that valuation occurs within the specific cultural logic subscribed to by some particular group of people. Theories of value should be *descriptive*, i.e., they should be based on the valuations that people actually make, not on what theorists claim to be an objective source of value. Normative theories of value make the mistake of inserting themselves on the same logical level as the phenomena they are to explain.

How, then, can we posit the occurrence of 'unequal exchange' without recourse to a normative theory of value? This can be done by analytically demonstrating that there is, in very general terms, a systematic relation between (a) flows of productive potential, (b) flows of 'utility' or exchange value (price), and (c) economic growth and the accumulation of capital. But this relationship is not usefully expressed as Marx or Odum would have it, that investment of labor or energy somehow translates into exchange value. Rather, there is a kind of *inverse* relation between productive potential and price that follows with logical necessity from the juxtaposition of the Second Law of Thermodynamics and the social institution of market exchange. We know that energy is not so much 'invested' as it is *dissipated* in a production process (Georgescu-Roegen 1971). Finished products must represent an increase in entropy compared to the resources from which they were produced, yet they must be priced higher. If we consider, longitudinally, the transformation of a given set of natural resources into an industrial product, Odum's measure of 'energy memory' must necessarily correlate positively with 'utility' or price, but objectively speaking, the amount of remaining available energy will be *negatively* correlated with price. As utility or price increases, there will be less of the original, available energy left. This means that industrial centers exporting high-utility commodities will automatically gain access to ever greater amounts of available energy from their hinterlands. The more energy they have dissipated today, the more 'new' energy they will be able to buy – and dissipate – tomorrow.

However, the logic of this argument has often escaped its critics (e.g., Brolin 2006: 262).

I was developing these ideas on the 'thermodynamics of imperialism' in the late 1980s (Hornborg 1989, 1992) without having yet encountered Stephen Bunker's (1985) important contribution on ecologically unequal exchange in Amazonia, which proved to contain several ideas which agreed with my approach, and some which seemed less useful (Hornborg 1998). Although most of the transfer of available energy to industrial sectors is dissipated in production, and a small share returned to their hinterlands in the form of industrial products and waste, a significant part of it is 'invested' in an expanding, industrial infrastructure, which through a self-reinforcing logic involving economies of scale (Bunker 1985) will tend to augment this process of accumulation and the unequal exchange of energy on which it is founded. This, of course, is a very different way of describing what the economists know as 'growth'. An intensification of industrial production will generally mean more competitive prices, expanding market shares, and rising profits for industrial sectors, which in turn means more purchasing power with which to appropriate even greater amounts of energy and other resources from peripheral sectors. An intensification of natural resource extraction, on the contrary, will ultimately lead to local resource exhaustion and ecological degradation, prompting investments to be shifted elsewhere and truncating cumulative economic expansion (ibid.).

Note again that although referring to Odum and Bunker, this account of unequal exchange is *not* tantamount to an energy theory of value, but rather the opposite. Like Marx, Odum, and Bunker argued, it is necessary to refer to another gauge than prices to assess the effects on 'development' of market exchange, but unlike their work this account avoids the pitfall of trying to objectively define value. In *not* offering an alternative theory of value, we not only avoid having to systematically contradict the valuations that people actually make, but are also free to suggest additional gauges of productive potential that could be used alongside energy and labor to illuminate processes of unequal exchange. A well-documented such metric, for instance, is the study of material flows and 'biophysical trade balances' (Fischer-Kowalski 1998; Pérez Rincón 2006; Weisz et al. 2006; Krausmann et al. 2009; Gierlinger 2010).

I have suggested that an additional such perspective, which integrates the concerns of Marxian and ecological economists, might be expressed as *the unequal exchange of time and space* (cf. Hornborg 2006), a formulation which conceives of 'time' and 'space' as human as well as productive resources. Human time can be saved as well as invested (as labor) in production, and the same goes for space (or land). When considered in relation to the fundamental rationale of most modern technology, this means that time and space can be redistributed in global society through unequal exchange. Most technology can be visualized as devices for 'saving' time or space: time by increasing velocity (e.g., railways, cars, airplanes) and space by intensifying the use of land (e.g., through high-rise buildings or modern agricultural machinery). What we seldom take into account is that this local 'saving' of time and space is made possible precisely by the expenditure or *loss* of time and space elsewhere in the global system. To give an early and fairly simple example, railways in the 1840s may have saved time – and accessed more space – for those who could afford to use them, but obviously at the expense of the underpaid labor time of vast armies of miners, loggers, steelworkers, and railway workers, as well as of the equally underpaid natural spaces where clear-cuts and strip mines were all that remained of the landscapes that had to be sacrificed in the name of technological progress.

The unequal exchange of time has to a large extent already been exposed by Marxian theory, notably in the work of Arghiri Emmanuel (1972) , who showed that low-wage countries have to export more products in exchange for a given volume of imports from high-wage countries than they would have needed to if the wage level had been uniform. Yet it is doubtful whether the Marxists themselves have fully grasped the implications of this analysis for our understanding of the very nature of modern technology. If machines from the very beginning of the Industrial Revolution can be visualized as devices for saving time *for some* at the expense of the time available to *others*, it would not make sense to view the 'development of the productive forces' as a cornucopia promising to emancipate the global proletariat.

If we add the more recent recognition, for example in the notion of 'ecological footprints' (Wackernagel/Rees 1996), that there is also an unequal exchange of *space*, such hopes of technological emancipation seem

even more untenable. The Industrial Revolution was not so much an absolute emancipation from land constraints as the local accumulation of a capacity to export and redistribute such constraints in global society (cf. Wilkinson 1973; Pomeranz 2000). It did not dissolve (European) land constraints once and for all as much as it provided Europe with ways of appropriating the land resources of other continents (Hornborg 2006). What the 'post-development' world might teach us is that technological 'progress' or 'growth' may not be the cornucopia that Ricardo and Marx generally believed, but local expressions of a kind of global zero-sum game. And what this means in terms of our understanding of concrete technology as a thoroughly *social* construct is even harder to digest, because it means that a tangible piece of machinery like a tractor or railway engine would *simply not be feasible* were it not for the uneven ways in which human time and natural space are *priced* in global society (Hornborg 2001). The contemporary, social condition of 'time-space compression', identified by the Marxian geographer David Harvey (1989), relies on global processes of *time-space appropriation*. The high-tech sectors of global society presently celebrating their efficient use of time and space appear largely oblivious of the extent to which this 'efficiency' has been made possible by exploiting vast investments of human time and natural space historically and presently made elsewhere in the world-system. Although such connections are generally concealed from their sight by virtue of geography or the passing of time, 'developed' sectors owe as much to slavery and ecological devastation as to genius and entrepreneurship.

Finally, as I have recently suggested elsewhere, even the net transfers of embodied labor can be mathematically converted into embodied land, viz., by multiplying embodied man-years by the average ecological footprints for the relevant category of laborers (Hornborg 2009: 250-251). This illustrates how, in biophysical reality, the relations between Ricardo's three factors of production (land, labor, and capital) are quite different from how they are conceived in mainstream economic models. Rather than being mutually substitutable, the three factors are asymmetrically related, with land the ultimate source of both labor and capital. Capital, from the start, was generated in the appropriation of other people's land and other people's labor.

I should emphasize again that I have been using the notion of 'unequal exchange' not in the moral sense of not getting one's money's worth, but in the naturalistic or realist sense of an objectively asymmetric transfer of some biophysical quantity or metric (*not* usefully referred to as 'value') by which the productive capacity of one social group is augmented at the expense of that of another. My argument is that industrial capitalism is founded and dependent on such objective, net transfers of productive potential. It is thus not a moral argument at the level of analysis, but can of course *issue* in a moral argument when articulated with the observation that an asymmetric transfer (net import) of energy or embodied land to one region or social group is the basis of a self-reinforcing accumulation of technological superiority and power vis-á-vis other regions or social groups.

2. How to disentangle the concept of 'unequalexchange' from earlier scholasticism

The second objection to my earlier work is that it would be useful to restrict the concept of 'unequal exchange' to the specific way in which it was applied by Arghiri Emmanuel (1972), viz., as a result of international differences in the price of labor. This view is fundamental to two doctoral theses recently produced at my own department at Lund University (Brolin 2006; Nordlund 2010). I would thus like to take this opportunity to address some conceptual issues that should be central to development studies. However, my focus here on Brolin's and Nordlund's approaches to these issues serves only to illustrate the kinds of miscommunication that such matters frequently generate. Together, these two contributions raise a number of questions that will be recognized as pivotal concerns of development studies in general.

Whereas most contributors to the discussion tend to assume an inevitable connection between theories of 'value' and theories of 'unequal exchange', I continue to maintain that the two concepts should be kept analytically distinct (Hornborg 1998, 2001). Briefly, as argued in section 1, unequal exchange is *not* a normative category, whereas an objectivist notion of value (i.e., one not simply equated with price) *is*. Much of the confusion regarding 'value' is necessarily highlighted in the ambition to

integrate a Marxian concern with the unequal exchange of labor, as in Emmanuel's (1972) calculations, with the ecological economists' concern with the unequal exchange of energy or embodied land. Like most Marxists – and although he momentarily pauses to acknowledge global Malthusian constraints – Emmanuel was a strong proponent of economic and technological growth. To bring Marxian and ecological economics together in a single theoretical framework thus necessarily requires transcending some major differences in fundamental assumptions.

As Brolin's (2006) detailed history of economic ideas shows, attempts to illuminate the operation of international exchange by defining sources of value can be traced through a series of paradigms ranging from mercantilists and Physiocrats to classical and neoclassical economists, Marxists, and ecological economists. With all due respect to the immense inputs of human time and intellectual energy invested in these deliberations over the centuries, it must be concluded, based on reading Brolin's thesis, that the scholastic obsession with a reified notion of value in the 18th, 19th, and 20th centuries is reminiscent, both in terms of scholarly output and ideological significance, of medieval theology. As any exegesis, such reviews will demand spending inordinate efforts on unraveling the contradictions and inconsistencies of individual scholars. While the history of such scholastic debates can be revealing, they can contribute little to demystifying the glaring inequities and ecological devastation of the modern world.

Emmanuel (1972: xxxi) writes that the most fundamental question in his study is whether it is a certain category of countries, rather than a certain category of products, that tends to be victimized by unequal exchange, defined by himself as the exchange of "a larger amount of their national labor for a smaller amount of foreign labor." In apparent agreement with this account, and with most readers of Emmanuel's treatise in the forty years since it was published, Charles Bettelheim (1972: 272) writes that "one of the chief conclusions of this work is that increase in economic inequality between nations is rooted in 'unequal exchange' ", defined as "the idea that on the world market the poor nations are obliged to sell the product of a relatively large number of hours of labor in order to obtain in exchange from the rich nations the product of a smaller number of hours of labor." Nevertheless, Brolin (2006) suggests that Emmanuel's account of unequal exchange is not about exchanging more labor for less. If indeed

most or even *all* (ibid.: 347) researchers in the field have committed the same mistake of interpreting Emmanuel's argument in terms of a 'net transfer' of labor (resulting from international wage differentials, also referred to as differences in factor costs), might not the problem be a certain lack of clarity in Emmanuel's analysis?

One reason why it seems inappropriate to concede the concept of 'unequal exchange' to Emmanuel's rather inaccessible definition is that the phenomenon of unequal exchange is much more general and inclusive than the specific structure of exchange that he identified between capitalist nations in the twentieth century. Unequal exchange in the sense of net transfers of resources has been fundamental to processes of accumulation in a wide variety of historical contexts, extending back in time at least to the earliest agrarian civilizations. Moreover, such processes of unequal exchange can be gauged in terms of several other biophysical metrics, in addition to labor. There seems no reason why scholars concerned with such processes should be compelled to abandon the simple and straightforward concept of 'unequal exchange' in favor of less appropriate and more cumbersome concepts (such as 'non-equivalent exchange'). It is thus encouraging to see the recent publication of a special issue of *International Journal of Comparative Sociology* devoted to 'ecologically unequal exchange' (Jorgenson/Clark 2009), and it would be unfortunate if scholastic disputes were to constrain some researchers explicitly committed to illuminating this theme in their attempts to provide contributions of modern relevance on this topic. By adopting Emmanuel's conceptual framework, a student of 'unequal exchange' will automatically become immersed in Marxist exegesis.

In his brief but concise *Conclusions*, Emmanuel (1972: 265) writes that unequal exchange is "one of the mechanisms whereby *value* is transferred from one group of countries to another" (italics added) and that "it enables the advanced countries to begin and regularly to give new impetus to that *unevenness of development* that sets in motion all the other mechanisms of exploitation and fully explains the way that wealth is distributed." He observes that economists "have been divided into objectivists and subjectivists, but unequal exchange is denied by both parties – by one party because for them exchange is always equal in a situation of equilibrium, and by the other because for them equal exchange does not exist" (ibid.). "On the basis of the classical and Marxist doctrine of labor *value*," Emmanuel

advises underdeveloped countries to "seek means to keep for themselves and prevent from leaking abroad the excess surplus *value* that they extract from their own workers" (ibid.: 267; italics added). These quotations from his *Introduction* and *Conclusions* will suffice to make it abundantly clear that Emmanuel's definition of 'unequal exchange' *was* initially presented as based on the idea that wage differences between countries generated international net transfers of labor 'value'. In order to account for international wage differences, Emmanuel refers to the demands of national labor movements, in part rooted in divergent cultural and historical experiences (Emmanuel 1972: 126-127).

As argued in section 1 above and elsewhere (Hornborg 2006), to attribute significance to the unequal exchange of embodied labor time is *not* necessarily to subscribe to a labor theory of value. The same applies to the unequal exchange of other productive resources such as energy or embodied land. However, to thus analytically disentangle the concept of 'unequal exchange' from theories of 'value' (whether of labor or land) tends to create major confusion among theorists who are used to grounding the former in the latter. This is probably the main source of misunderstandings and disagreements on unequal exchange. Although this is evident in Brolin's (2006) study, it does provide a useful history of ideas relating to both 'value' and 'unequal exchange', from Cantillon and Quesnay through Smith, Ricardo, and Marx to Innis, Prebisch, Lewis, and Emmanuel, and finally Odum, Bunker, and Martinez-Alier (ibid.: 335-354). The study's objection to the idea that ecologically unequal exchange is relevant to understanding uneven development is largely based on Bairoch's (1993) conclusion that the 'developed West' had no need for extractive peripheries prior to 1955, a notion that I have dealt with elsewhere (Hornborg 2007: 20-21; Pomeranz 2000). Like Bairoch, Brolin dismisses the idea that net appropriation of natural resources had any significance for development or world-system positionality.

Carl Nordlund's (2010) study also reviews the history of the idea of ecologically unequal exchange, but as background to an empirical investigation, applying the tools of social network analysis, of actual international trade in fuels and agricultural commodities. The trade in these commodities is quantified in terms of exchange value (money prices) as well as biophysical metrics, viz. energy content for fuels and embodied

land (ecological footprints) for agricultural products. Nordlund's point of departure is that "it is difficult to deny the existence of some kind of ecological unequal exchange" (ibid.: 15), that the contemporary world-system is "brutally unfair in terms of resource consumption" (ibid.: 18), and that "the gaps between the haves and the have-nots" have increased with the growth in international trade (ibid.: 152). His "core question" is whether "there is a relationship between structural positionality [in the world-system] and ecological unequal exchange" (ibid.: 18) and whether this is related to "global differences in factor costs (of natural resources)" (ibid.: 22), a phrasing of (ecologically) unequal exchange that is presented as more in line with Emmanuel's account than with those of more recent theorists. In Nordlund's words, while Emmanuel "examined the national price-differentials for labor (i.e. wages), this thesis looks at price-differentials of another factor of production: land (and natural resources)" (ibid.: 181). Although Nordlund's reasoning is generally clear and consistent and his methodology both innovative and sophisticated, his approach raises some conceptual issues that deserve to be discussed.

Nordlund (ibid.: 178) claims that recent theorists of ecologically unequal exchange "are not concerned with" factor costs and the "underlying mechanisms" leading to net transfers of biophysical resources between nations, and that my own and Bunker's contributions are "quite far away from the fundamental theoretical stanzas found in the dependency school and world-system analysis." However, 'factor cost differentials' is merely another way of talking about relative differences in the prices of land, labor, and capital, which I have consistently viewed as an obvious 'underlying mechanism' (but inseparable from political, cultural, and other aspects) behind unequal exchange and capital accumulation (Hornborg 1998, 2001, 2006, 2009). Rather than contrasting Emmanuel's concern with 'factor costs' against others' concern with 'net transfers', as if they were exclusive options (Nordlund 2010: 264-265), they are clearly two aspects of the same total social phenomenon of unequal exchange. Moreover, rather than attribute international wage differentials to the different cultural backgrounds of Britons, Spaniards, and French, as does Emmanuel (1972: 126-127), I have consistently been concerned with their relation to world-system positionality. This is certainly more fundamental to my argument over the years than a recent "hint" (Nordlund 2010: 175).

It has been proposed that I cannot explain "why" the periphery "chooses" to submit to ecologically unequal exchange benefitting the core (ibid.: 173-174), as if being exploited was ever a matter of choice. Apparently, my argument that the cultural evaluations of consumers are irrelevant to the physical reality of resource dissipation in economic processes (Georgescu-Roegen 1971) has mistakenly been interpreted as a dismissal of 'utility' as a driver of consumption. Such a conclusion confuses my dismissal of the role of 'utility' in a thermodynamic account of economic processes with my view of its role in actual economic behavior.

Finally, the suggestion that a calculation including flows of *information* "could very well tip the scales of the whole equation, resulting in thermodynamic unequal exchange in the very opposite direction to what is intuitively perceived" (Nordlund 2010: 174) would run counter to the idea, expressed by Bunker, myself, and other world-system analysts, that development in core areas is tantamount to an accumulation of complexity, to the detriment of increasingly impoverished peripheries. 'Complexity' and 'impoverishment' *are* measures of (high versus low) information. The notion of core areas as cornucopias, exporting net flows of information to their peripheries, seems very much in line with mainstream economic theory, following an ideological tradition succinctly expressed in Rudyard Kipling's image of colonialism as the 'White Man's Burden'. We are reminded of Maurice Godelier's (1986) observation that unequal exchange tends to present itself as reciprocity, or even charity.

Although Nordlund (2010: 19) appears to endorse my rejection of what Paul Ehrlich has called "crackpot rigor", and although he momentarily expresses doubts about quantification (ibid.: 264), immersion in the technical complexities of social network analysis can lead to conclusions that are very far removed from the conviction that the contemporary world-system is 'brutally unfair'. The suggestion (ibid.: 264) that studies of specific commodity flows are better at identifying ecologically unequal exchange than studies of national indicators of consumption, such as ecological footprints, risks isolating distinct commodity flows (fuels versus agricultural products) to the point of obscuring the occurrence of ecologically unequal exchange. Thus, for example, the huge imports of fuels to the United States are never related to its huge exports of agricultural products (measured in hectares), although it should be obvious that the latter are largely made

possible by the former. Instead, these agricultural exports – and flows of agricultural commodities in general – are simply interpreted as an invalidation of Nordlund's version of the hypothesis of ecologically unequal exchange (ibid.: 273-277). The focus on specific commodity flows, and on the comparison of monetary and biophysical measures of these flows, may thus have obscured the total socio-ecological metabolism of which they are a part, including the conversion of imported fossil fuels into agricultural exports (see Singh and Eisenmenger, this issue, for an empirical illustration of ecological unequal exchange based on the social metabolism of nations). The complex relation between embodied energy and embodied land, which this example highlights, will be addressed in the third and final section. Let us just conclude that although both Brolin's (2006) and Nordlund's (2010) conclusions on ecologically unequal exchange are largely negative, their struggles have been instructive. To paraphrase Wallerstein (1995), we need to hold the tiller firm as we try to navigate between the Scylla of scholasticism and the Charybdis of methodological fetishism.

3. Conclusions: The historical contextuality of ecologically unequal exchange

This concluding section elaborates some recent reflections (Hornborg 2009) on the conceptual challenges raised by the idea of ecologically unequal exchange. From a comparative, historical perspective, it is obvious that different kinds of environmental load displacement (through trade) will accompany specific kinds of capital accumulation. We thus need to use different measures of ecologically unequal exchange for different historical and geographical contexts. What they all have in common is a concern with the factor of production referred to as 'land', a factor which, as Nordlund (2010) observes, has been largely neglected by mainstream economists over the past two centuries. Different kinds of environmental load displacement reflect the different kinds of technological infrastructures that are being accumulated, as well as the particular resource endowments offered by specific geographical circumstances. Thus, the concern with 'land' must include not only embodied, eco-productive hectares, but also embodied energy, materials, carbon dioxide emissions, environmental

degradation, water, etc. (cf. Jorgenson/Clark 2009). Different factors will be crucial bottlenecks at different times and different places. For example, 19th century Europe was in great need of additional eco-productive hectares (Wilkinson 1973; Pomeranz 2000), but was more than self-sufficient in mineral energy (Bairoch 1993; Brolin 2006). Conversely, 21st century United States is in great need of imported energy, but is more than self-sufficient in agricultural land (Nordlund 2010). Against this background, it is completely logical that European colonial wars were fought over land, while contemporary American wars in the Middle East are being fought over oil. Biophysical trade balances indicate that Europe, the United States, and Japan all import significantly more materials than they export, while the converse applies to most South American countries. It is well known that per capita ecological footprints and 'carbon footprints' are similarly skewed in favor of developed nations. Taking all these different circumstances into account is difficult but necessary, if we wish to generate a coherent understanding of ecologically unequal exchange. If we are indeed convinced that the world-system is 'brutally unfair', our research questions and methodologies need to be grounded in a conceptual framework that will not be undermined by statistics that seem to invalidate a superficial, single-metric theory of unequal exchange.

Let us conclude with a final observation on the historical relation between energy and embodied land, arguably the two most likely metrics for studies of ecologically unequal exchange. Up until the Industrial Revolution, energy and land were one and the same, converging in the production of food for human labor and fodder for draught animals. For two centuries now, the age of fossil fuels has kept land requirements and energy requirements distinct from each other, making it possible for historians such as Bairoch (1993) to seriously propose that European expansion had no need for extractive peripheries (but cf. Hornborg 2006, 2007; Pomeranz 2000). During this period, ecologically unequal exchange has not always involved net transfers of energy, nor has it always involved net transfers of embodied land, but it has always involved net transfers of *one* of these resources. As we are currently contemplating that peak oil and climate change may prompt us to turn to 'agrofuels', we are in fact imagining a future where land requirements and energy requirements will once again coincide. Once again, it seems, it will be possible to calculate the costs of

transport distances in terms of eco-productive space. What this might entail in terms of our total world view and global social metabolism is beyond the scope of this paper, but if we shall once again see competition over scarce land for food, fodder, fibres, and fuel, we may rest assured that the realities of 'ecologically unequal exchange' and 'environmental load displacement' will be recognized as very tangible conditions of human existence. In such a future, also, ecologically unequal exchange will again involve concerns with *both* energy *and* embodied land. In terms of economic theory for understanding the course of history, this would amount to the bankruptcy of both Ricardian and Marxian concepts of 'labor value' in favor of a cosmology more akin to pre-industrial Physiocracy.

Suffice it to observe, at this point, that if the United States were to import best-practice, Brazilian ethanol (disregarding here the extent to which this ethanol is in fact subsidized by fossil fuels) to replace its current net *imports* of fossil fuels, it would require approximately 187 million hectares of Brazilian sugarcane[2], which is more than seven times the agricultural area within the United States presently devoted to export production. The current land area in Brazil devoted to sugarcane ethanol is around 4 million hectares. The long-term implications of the global energy shifts we shall be witnessing over the next few decades may very well lead to the conclusion that much of what we have come to know as 'industrial' technology is feasible only when it requires less land area than the same work conducted by humans and draft animals. This has indeed been the case through two centuries of fossil fuel energy, but at the moment we have no reason to believe that this specific kind of rationality will extend beyond the fossil fuel era.

1 The first half of this paper in part overlaps with Hornborg (2003).

2 Kenneth Hermele, personal comment 2011.

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Abstracts

The acknowledgement of asymmetric transfers of material, biophysical resources such as energy, matter, embodied land, and embodied labor is fundamental to understanding not only development gaps, but the very phenomenon of 'technology' as a social redistribution of resources. This paper argues that to posit the occurrence of ecologically unequal exchange does not need to imply a value judgement, or being constrained by the approach to unequal exchange provided by Arghiri Emmanuel. During two centuries of fossil fuels, ecologically unequal exchange has not always involved net transfers of energy, nor has it always involved net transfers of embodied land, but it has always involved net transfers of one of these resources. In a future dominated by biofuels, ecologically unequal exchange will again involve concerns with both energy and embodied land. In terms of economic theory for understanding the course of history, this would amount to the bankruptcy of both Ricardian and Marxian concepts of 'labor value' in favor of a cosmology more akin to pre-industrial Physiocracy.

Die asymmetrischen Transfers von stofflich-biophysikalischen Ressourcen wie Energie und Material sowie die Inanspruchnahme von Land (*embodied land)* und Arbeit zur Kenntnis zu nehmen, ist eine zentrale Voraussetzung, um nicht nur Entwicklungsunterschiede zu verstehen, sondern insbesondere das Phänomen der Technologie als soziale Umverteilung von Ressourcen. Dieser Beitrag argumentiert, dass die Feststellung von ökologisch ungleichem Tausch weder auf Werturteilen basieren noch mit dem Ansatz von Arghiri Emmanuel zu ungleichem Tausch begründet werden muss. Während zweier Jahrhunderte der Nutzung fossiler Energieträger, implizierte ökologisch ungleicher Tausch nicht immer den Nettotransfer von Energie, auch nicht immer den Nettotransfer von *embodied land*, jedoch immer den Nettotransfer einer der beiden Ressourcen. In einer Zukunft, die durch Biotreibstoffe geprägt ist, wird ökologisch ungleicher Tausch sich erneut mit Fragen nach Energie und *embodied land* auseinandersetzen müssen. Im Hinblick auf ökonomische Theorien, welche den geschichtlichen Verlauf erklären, würde dies ein Scheitern von Arbeitswerttheorien – sei es nach Ricardo oder nach Marx – bedeuten, zugunsten einer Kosmologie nach dem Modell der vorindustriellen Physiokraten.

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