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Ecological Unequal Exchange: Consumption, Equity, and Unsustainable Structural Relationships within the Global Economy

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Abstract
We discuss and elaborate upon the theory of cross-national ecological unequal exchange. Drawing upon world-systems theoretical propositions, ecological unequal exchange refers to the increasingly disproportionate utilization of ecological systems and externalization of negative environmental costs by core industrialized countries and, consequentially, declining utilization opportunities and imposition of exogenous environmental burdens within the periphery. We provide a descriptive overview of theoretical and empirical efforts to date examining this issue. Ecological unequal exchange provides a framework for conceptualizing how the socioeconomic metabolism or material throughput of core countries may negatively impact more marginalized countries in the global economy. It focuses attention upon the global uneven flow of energy, natural resources, and waste products of industrial activity. Further, the recognition of the distributional processes of ecological unequal exchange is relevant to considerations of both the socioeconomic and environmental imperatives underlying the pursuit of sustainable development, as it contributes to underdevelopment within the periphery of the world-system. We conclude by highlighting the interconnections between uneven natural resource flows, global environmental change, and the challenge of broad-based sustainable development.

Key words: ecological footprint • ecological unequal exchange • international trade • natural resource consumption • sustainable development

1. INTRODUCTION

Viewed from nighttime satellite photos, the luminous agglomerations of the built industrial and urban infrastructure of the countries at the core of the global economy are readily discernable against the relatively empty expanses characterizing the periphery. This illumination is only loosely coincident with the distribution of population density around the globe. It is, however, tightly linked to the validity of a core–periphery division regarding the flow and consumption of energy and materials within the global economy (Hornborg, 2001). Mainstream theories of development and underdevelopment have failed to sufficiently consider such ecological dynamics (Bunker, 1985). The incandescent presence of the industrial technomass and the empty expanses of the periphery do not exist in isolation but are interwoven, a reflection of not simply domestic processes but the socioeconomic metabolism or material throughput of the world-system. In turn, systemic global patterns of ecological access, utilization, and degradation shape the uneven development of human societies.

The built infrastructure and complex social organization of the developed countries is reliant upon the extractive economies of many less developed countries (LDCs).[1] The trade of natural resources supports the disproportionate per capita material consumption rates typically characteristic of core countries. Ecological flows, when systematically undervalued in monetary terms, displace the environmental costs of this uneven consumption to LDCs. In addition, it allows core countries to inequitably appropriate limited global environmental space or carrying and sink capacity of ecological systems well beyond their own borders.

To more fully conceptualize uneven development it is necessary to examine the ecological basis of these interdependencies. To better understand global environmental change, it is instructive to evaluate their consequences. This requires, moreover, the evaluation of international political economy dynamics cast in biophysical and not simply monetary terms.

Towards this end, we draw together various strands of thought to elaborate upon the theory of ecological unequal exchange, a perspective gaining attention among social scientists.[2] Ecological unequal exchange refers to the increasingly disproportionate utilization of ecological systems and externalization of negative environmental costs by developed countries and, consequentially, declining utilization opportunities and imposition of exogenous environmental burdens within LDCs. The focus, therefore, is upon the interdependent distributional processes shaping cross-national environmental outcomes.

Ecological unequal exchange endeavors to conceptualize the cross-national processes and structural relations perpetuating the unbalanced flow of energy and materials within the world-system, shaping patterns of uneven development. It is focused upon the cross-national contingencies underlying the variable socioeconomic metabolism between the core, semi-periphery, and periphery in a manner not previously envisioned by traditional theories of development/underdevelopment. This perspective is relevant to a more comprehensive understanding of the mechanisms of global environmental use and degradation, the variable consequences of economic globalization, and concern with broad-based and equitable sustainable development. It forces consideration of the environmental foundation of human societies as constituted by domestic and exogenous forces disproportionately shaping and constraining ecological burdens and advantages cross-nationally.

Our elaboration incorporates and synthesizes complementary insights from world-systems theory, political ecology, ecological economics, and anthropology. Indeed, the theory of ecological unequal exchange is most profitably drawn from the unexplored interface of different disciplinary boundaries (Hornborg, 2001). Our goal is to contribute to the debate concerning processes of uneven development by pulling together ideas and arguments from numerous perspectives united by an overarching proposition: the core–periphery hierarchy is shaped by and, in part, perpetuated through uneven cross-national access to and utilization of ecological resources and services.

We begin by synthesizing different conceptions of ecological unequal exchange processes in the academic literature in an effort to provide a concise definition that captures its most substantive aspects. Second, we delineate the processes by which ecological unequal exchange is generated at a cross-national level. Third, we illustrate the macrostructural empirical outcomes arguably shaped by processes of ecological unequal exchange. In particular, we examine environmental cost-shifting and inequitable appropriation of environmental space within the world-system. We conclude by reiterating the unsustainable structural interconnections and distributional processes within the world-system that present a challenge to pursuit of broad-based sustainable development.

2. ECOLOGICAL UNEQUAL EXCHANGE IN THE WORLD-SYSTEM

Central to world-systems theory is the concept of unequal exchange. It is one mechanism reinforcing differential power and position in the world economy between nations through the transfer of surplus value. Emmanuel (1972) formulated a specific definition of unequal exchange, attempting to specify its particular mechanisms. He argues trade generally consists of the export of capital intensive, high wage products from industrialized countries in exchange for labor intensive, low wage products from the periphery. Wage differentials, moreover, cannot be explained simply as the consequence of divergent labor productivity but are strongly influenced by historical development patterns that have largely protected disproportionate wage rates in the industrialized countries. Low wage rates in the periphery are perpetuated by the substantial cross-national immobility of labor but relatively greater mobility of core investment capital, allowing access to the abundance of reserve labor in LDCs. As a consequence, Emmanuel argues, international trade reinforces differential cross-national wage rates and contributes to relatively higher labor exploitation in peripheral countries. This exchange is unequal as capitalists within industrialized countries capture significant portions of the labor value that otherwise would accrue within the periphery (Emmanuel, 1972).

In addition to the transformative dynamics of labor, human societies require the continual appropriation of energy and raw materials from and externalization of waste products or pollution with ecological systems. Socioeconomic metabolism refers to this cycling of biophysical flows between human societies and ecological systems (Fischer-Kowalski and Haberl, 1998). Further, human societies are interwoven into systemic patterns of cross-national exchange of energy and natural resources. Structured relations forged through international trade shape the socioeconomic metabolism of countries at different positions in the hierarchy of the global economy. Such interactions shape the socioeconomic metabolism of the world-system more broadly, constituting the material foundation of capital accumulation and standards of living of human societies.

The socioeconomic metabolism of the world-system consists of the interdependent flows of energy, natural resources, and waste products between countries as it shapes the differential processes of production-consumption-accumulation at different positions in the global economy. The patterns reflected in nighttime satellite photos are indicative of these flows, and a testament to the ecological basis of the core–periphery divide (Hornborg, 2001).

Ecological unequal exchange is increasingly recognized as a mechanism, in addition to labor exploitation, underlying the socioeconomic and environmental disparities between developed countries and LDCs and as a regulative mechanism shaping the socioeconomic metabolism of the world-system. Diverse strands of research in political ecology, world-systems theory, anthropology, and ecological economics are focused upon such ecological distributional patterns (Andersson and Lindroth, 2001; Bunker, 1985; Giljum and Eisenmenger, 2004; Hornborg, 1998a, 1998b, 2001; Jorgenson, 2003; Muradian and Martinez-Alier, 2001a). Capital accumulation is fundamentally rooted in alteration of ecological systems and the exploitation of labor (Bunker, 1985; Hornborg, 2001). It shapes both the social relations of production and the structure and integrity of ecological systems.

Ecological unequal exchange maintains that countries advantageously situated within the structural interaction networks of global exchange are more likely to secure favorable terms of trade promoting disproportionate access to natural resources and sink-capacity services of ecological systems. In turn, this access facilitates the externalization of many of the negative environmental consequences of domestic production, consumption, and disposal activities supporting their standard of living and maintenance of their built industrial infrastructure.[3] Further, we argue the macrostructural empirical consequences of ecological unequal exchange are manifested in three interrelated processes:

1) *Environmental cost-shifting* or externalization of the social and ecological costs of extraction and distribution of natural resource exports from LDCs, enhancing environmental degradation and depletion at the local level.
2) The disproportionate and uncompensated utilization of global *environmental space* or available sink-capacity and biologically productive area, limiting utilization opportunities of LDCs.

3) Environmental cost-shifting and appropriation of environmental space contribute to *processes of underdevelopment* within LDCs. Underdevelopment is a consequence of the loss of value associated with the export of undervalued natural resources, diminishing socioeconomic opportunities.

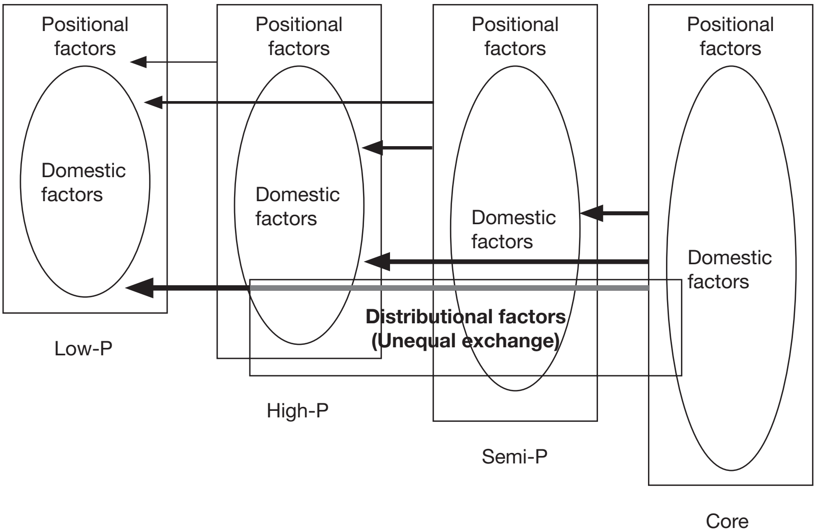
Ecological unequal exchange builds upon and complements social science research focused upon the driving forces of global environmental change but endeavors to evaluate the non-linear and contingent dynamics underlying differential environmental burdens and opportunities facing countries at divergent hierarchical positions in the world-system. This focus is based upon the increasing recognition of many non-monotonic relationships between position in the world-system and environmental outcomes (Burns et al., 1997). Although energy consumption tends to increase in a linear manner with world-system position, for example, deforestation rates are non-monotonic as the greatest impacts are located outside the core countries (Burns et al., 1997), despite the fact that forest product consumption is significantly greater in the core (Loh and Wackernagel, 2004).

An overly simple model of core–periphery exploitation is arguably inadequate for conceptualization of ecological unequal exchange dynamics. Contributing to the complexity of global environmental utilization and change, there is likely to be recursive exploitation as well wherein semi-peripheral countries with international exchange advantages over peripheral countries displace or externalize negative environmental outcomes at their expense (Burns et al., 2003). Deforestation, for example, has in previous decades been more pronounced in the semi-periphery but over the 1990–2000 period appears more prominent within the periphery, arguably shaped in part by the increasing influence of logging industries based in semi-peripheral countries (Burns et al., 2003).

In addition, economic and environmental outcomes do not simply vary by world-system position but interact with world-system processes (Burns et al., 1997), as well as domestic factors. Accordingly, there is a need to theoretically specify where, when, and under what specific conditions various environmental impacts tend to occur within the world-system (Burns et al., 2003). This suggests greater emphasis upon theoretical scope conditions sensitive to temporal changes in economic, political, and technological dynamics within and between positions in the world-system.

In order to situate the discussion of ecological unequal exchange within previous analysis from a world-systems approach, Figure 1 distinguishes our distributional focus from the domestic and positional analytical levels.[4] All three can be analytically separated but, ultimately, are mutually constituted to a significant degree, in essence interdependent 'layers' contributing to the complexity of global social and environmental change. Accordingly, we envision three broad, conceptual levels within the world-systems perspective relevant to examination of socioeconomic and environmental change, illustrated in

Figure 1 Analytical levels within the world-systems perspective



Note: Low-P = low periphery; High-P = high-periphery; Semi-P = semi-periphery

Figure 1. These include: 1) domestic, 2) positional or structural location *within* world-system positions, and 3) distributional or *between* world-system position processes.

Domestic Level Processes – examination of positional location within the world-system or the distributional processes of between position dynamics are arguably insufficient for conceptualizing all environmental outcomes. Countries within world-system positions can exhibit considerable variance on particular environmental indicators, a testament to the importance of internal factors, even as there often tends to be recognizable patterns or structural similarities across world-system positions on these same indicators, suggesting the validity of external factors as well. The social organization of production and consumption, population growth, political structure, civil society social movements, degree of labor organization, and other domestic dynamics are relevant explanatory factors, although from a world-systems perspective domestic processes are never truly divorced from the larger structural context.

For example, carbon dioxide emissions inefficiency is relatively greater in countries characterized by higher military spending, irrespective of world-system position (Roberts et al., 2003). Nonetheless, political regime repressiveness is also positively associated with carbon dioxide emissions inefficiency but the effect is the most salient within countries outside the core (Roberts et al., 2003).

Positional Level Processes – despite the explanatory validity of domestic processes, there are often structural similarities or general tendencies within world-system positions. Arguably, these positional dynamics are shaped by the variable historical incorporation of different regions of the world into the capitalist global economy and the subsequent development opportunities that are available. Countries residing in the periphery, for example, are less inclined to sign international environmental treaties (Roberts, 1996). However, holding world-system position constant, there is also evidence that countries with more repressive political regimes and greater military spending are also less likely to sign environmental treaties (Roberts, 1996). Further, research illustrates the positional or zone specific impact of urbanization upon deforestation is strongest in the periphery and semi-periphery, while percent of the population composed of adults, the most economically active segment, is only significantly related to deforestation in semi-peripheral countries (Burns et al., 2003). This research illustrates that not only do rates of forest cover change vary systematically by world-system position but so do the driving socio-economic forces of deforestation.

Distributional Level Processes – distributional dynamics between positions in the global economy is at the heart of world-systems analysis (Chase-Dunn and Grimes, 1995; Wallerstein, 1974). Such relational processes both shape and stabilize the hierarchical structure of the global economy. Numerous studies based upon a network analysis methodology provide evidence of the asymmetrical structure of global economic and political relations or an identifiable ‘form’ to international exchange relations (Mahutga, forthcoming; Nemeth and Smith, 1985; Smith and White, 1992; Snyder and Kick, 1979).

Relevant to considerations of distributional dynamics between world-system positions, research by Grimes and Kentor (2003) reveals foreign capital investment in LDCs is positively associated with growth in total CO_2 emissions. This is consistent with the argument that energy intensive core production is increasingly relocating to non-core countries where environmental controls are less stringent (Grimes and Kentor, 2003).

Processes of ecological unequal exchange are fundamentally distributional but we anticipate that such factors interact with both domestic and positional dynamics. The direction and weight of the arrows in Figure 1 further suggest that we would expect the negative impacts of distributional processes to be greatest between the core and low-periphery, and less so between the core and the high-periphery and semi-periphery. This is consistent with the hierarchial structure of the world-system (Wallerstein, 1974) and Galtung’s logic of imperialism through trade relations (1971).

Examination of ecological unequal exchange is oriented towards further refinement in conceptualizing the layers and complexity of global environmental and social change within the world-system. The global economy is based upon an increasingly internationalized environment wherein economic and political interests far from the physical location of specific resources influence their form and utilization (Redclift, 1987). Accordingly, environmental outcomes are increasingly the consequence of transnational processes, and ecological systems are more appropriately envisioned as continually in 'process' rather than unchanging (Redclift, 1987). Ecological conditions are the temporal culmination of social relationships, variously manifested at divergent geographic scales, consisting of the malleable interaction of physical space, natural resources, and economic forces, rather than predetermined or static (Redclift, 1987).

The Generation of Ecological Unequal Exchange

Bunker's detailed history of the incorporation of the natural resources of the Brazilian Amazon into the global division of labor is an early example illustrating the ecological side of unequal exchange (1984, 1985, 2003). He stresses that theories of development/underdevelopment have failed to account for the fact that extraction and export of natural resources from LDCs constitute both: 1) a transfer of value embodied in matter and energy; and, 2) extractive activities at one point in time shape the ecological, demographic, organizational, and infrastructural context in which subsequent development efforts are situated, often complicating future value-added production in resource extraction oriented LDCs.

Theories of development/underdevelopment have insufficiently recognized the fundamental differences regarding the internal dynamics and logic of accumulation between extractive and productive economies (Bunker, 1984, 1985). This distinction is crucial as Bunker locates the origin of ecological unequal exchange within the interdependent but differing internal dynamics of each (1984, 1985). It is not extraction of natural resources and energy, per se, that promotes ecological unequal exchange but the social organizational consequences this tends to produce between exporting and importing regions. The historical interactions between modes of extraction and production create path dependent dynamics that are often difficult, although not impossible, to transcend (Bunker, 1984, 1985).

Modes of extraction constitute the class structure, organization of labor, property relations, activities of the state, and physical infrastructure of subnational regions oriented towards the export of geographically and topographically site-specific and unique natural resources (Bunker, 1985). The export of monetarily undervalued natural resources from modes of extraction is characterized by a loss of value that cannot be measured solely in terms of the appropriation of surplus labor (Bunker, 1985). However, labor reorganization and exploitation within modes of extraction is also crucial to the unequal appropriation of value between the core and the periphery (Bunker, 1985). The mechanisms of exploitation and underdevelopment reside, therefore, in the complex interaction of internal and external forces, the unequal appropriation of value from labor and nature (Bunker, 1985).

Productive economies, in contrast, are characterized by a division of labor, spatial organization of firms and enterprises, technological capacity, and physical infrastructure oriented towards the multitude of complex processes of value-added production (Bunker, 1985). The energy and materials that flow through productive economies in the developed countries is partially conserved in useful forms that include the built infrastructure and physical and human capital, promoting complex social and economic organization. Conversely, retention of energy and materials in extractive economies often proves problematic. This promotes the simplification of social and economic organization over time. Further, Bunker argues:

> Analysis of energy flows between regions and of different uses of energy in different regional formations provides a much fuller explanation of uneven development than any drawn from conventional economic models. If energy and matter necessarily flow from extractive to productive economies, it follows that social and economic processes will be intensified and accelerated in the productive economy and will become more diffuse and eventually decelerate in the extractive economy. The flow of energy and matter to productive societies permits the increased substitution of nonhuman for human energies, allows for increased scale, complexity, and coordination of human activities, stimulates an increasing division of labor, and expands the specialized fields of information which this entails. (1985: 47)

Ecological unequal exchange, therefore, is contingent upon differential cross-national social organization and accelerated production-consumption-accumulation linkages in the developed countries facilitating the ability of state and private capital interests to determine global demand for natural resources (Bunker, 1985; Hornborg, 2001). The capacity to control demand ensures core interests engage in the substantive decisions regarding global export oriented activity and subjects peripheral countries to ever-changing market forces (Bunker, 1985). Local populations, social organization, infrastructure, and ecosystems within extractive regions in LDCs are often continually disrupted in the face of malleable core needs. Extractive regions failing to reorganize to conform to core interests, in turn, are likely to be subject to declining terms of trade or abandoned entirely in lieu of natural resource exports originating elsewhere.

The origin of ecological unequal exchange arises from this complex interplay between modes of production and extraction both at the local and the global level and the consequent transfer of value embodied in energy and natural resources (Bunker, 1985; Hornborg, 2001). The social organization of human energy into a complex division of labor, characterized by the coordination of specialized tasks acting upon a continual flow of undervalued raw materials, is an important dimension shaping the production and reproduction of differential cross-national social and economic power (Bunker, 1992). Power over natural resources, therefore, is interwoven with economic and social power (Bunker, 1992).

Similar to Bunker's analysis, Hornborg locates the origin of ecological unequal exchange within the asymmetric transfer of energy and materials laden with productive potential primarily captured or realized within importing centers of world economic power (2001). This contributes to the cycle of expanding industrial production and consumption within industrialized countries and deceleration within LDCs, visible in nighttime satellite photos (Hornborg, 2001). There is, moreover, an inverse relationship between productive potential and economic value (Hornborg, 1998b). Unlabored and semi-processed natural resources possess considerable productive potential that is dissipated along the production chain. Economic value tends to grow inversely with the realization of this concrete, productive potential. Finished products, in turn, contain diminished productive potential but enhanced economic value and utility, the control of which facilitates the acquisition of even greater raw, unlabored energy and materials necessary to maintain and expand the industrial technomass (Hornborg, 1998b).

This systematic appropriation of energy and materials, and consequent realization of economic value, is the foundation of the industrial infrastructure reproducing cross-national inequalities in the world economy and uneven ecological outcomes (Hornborg, 1998b). Congruent with Bunker, Hornborg argues differential cross-national social power, in turn, is based upon historically contingent social relationships forged through the ability to control asymmetrical flows of environmental resources and risks (Hornborg, 2001). The mechanisms of development/underdevelopment are at least partially rooted in spatial, material realities. Hornborg argues:

> The luminous agglomerations of industrial infrastructure in the satellite photos are the result of uneven flows of energy and matter, and these processes of concentration are self-reinforcing, because the increasingly advantageous economies of scale in the center progressively improve its terms of trade and thus its capacity to appropriate the resources of the hinterland. Extractive economies are thus pressed to overexploit nature, while those parts of the landscape in industrial nations that have not been urbanized can instead be liberated from the imperative to yield a profit and rather become the object of conservation programs. (2001: 29)

In sum, both Bunker and Hornborg imply more than simply reliance of core industrialized countries upon undervalued natural resource assets from the periphery, as they are articulating a model of acceleration and social organizational complexity and deceleration and simplification between productive and extractive economies. In tandem, productive economies gain flexibility and adaptability while extractive economies become increasingly rigid, inflexible, and vulnerable to the shifting demands of global capital accumulation.

Undervaluation of Natural Resource Flows

Differential social, economic, and political power shapes the terms of trade characterizing natural resource flows from LDCs (Hornborg, 2001; Martinez-

Alier, 2002) Power, therefore, constitutes a factor of production proceeding actual production, supporting the techno-economic maintenance and growth or 'development' of industrial countries (Hornborg, 2001). Undervaluation of natural resource exports is, thus, a key mechanism of ecological unequal exchange, ultimately shaped as a consequence of variable cross-national power and advantage in international exchange relations.

Further, undervaluation is less about market failures than successful appropriation of natural resources by more powerful trading partners, without internalization of the full ecological and social costs (Muradian and Martinez-Alier, 2001a). Martinez-Alier and O'Connor (1999) suggest cross-national income distribution and economic valuation are not independent, thus shaping the imposition of negative externalities. This is because the 'poor sell cheap' (Martinez-Alier and O'Connor, 1999: 380). Powerful industrial lobbies in core countries strive to maintain asymmetric trade relationships enhancing domestic employment, profits, and government revenues (Arden-Clarke, 1992). The result is ecological distributional conflicts across countries not easily captured or conceptualized from a neoclassical economics perspective, which is generally optimistic about the prospects of internalizing environmental and social costs.

'Prices' are, in part, socially negotiated exchange relationships that may not necessarily reflect real material flows, including the energy and productive potential embodied in these flows and the environmental and human health costs incurred (Hornborg, 1998b). Although trade appears balanced in monetary terms, the apparent confluence of impersonal market forces of supply and demand, there may nonetheless be an inequitable exchange of energy, productive potential, and sink-capacity demand among trading partners (Andersson and Lindroth, 2001). Undervaluation, in turn, allows developed countries to increase their relative share of the world-system's total purchasing power at the expense of those providing cheap labor, energy, and raw materials (Hornborg, 1998a).

Further, exogenous factors arguably shaping monetary undervaluation of natural resource exports from LDCs include: external debt obligations, austerity requirements of structural adjustment policies, import protectionism within industrialized countries, the inability to diversify into non-primary product exports, and low revenue capture. Less developed countries under heavy external debt obligations often engage in increased resource exploitation to meet these demands (Arden-Clarke, 1992). This contributes not only to resource degradation as the pace of harvesting outpaces natural replacement rates but inadvertently contributes to the oversupply of natural resources on the world market and declining terms of trade (Muradian and Martinez-Alier, 2001a). This 'desperation production' complicates efforts to internalize environmental costs in LDCs and contributes to consumption of resources in the developed countries, as underpricing provides few incentives for conservation efforts (Arden-Clarke, 1992). Further, most value-added processing of traded natural resources occurs in developed countries, contributing to low rates of revenue capture in LDCs (Arden-Clarke, 1992). This complicates, in turn, acquisition of financial and technical resources that could be applied to more sustainable methods of commodity extraction and distribution at the local level (Arden-Clarke, 1992).

Environmental Cost-Shifting

A conundrum hints at the existence of environmental cost-shifting: nations with higher levels of natural resource consumption generally experience lower domestic levels of natural resource degradation, a process sometimes referred to as the 'consumption/environmental degradation paradox' (Jorgenson, 2004, 2006; Jorgenson and Rice, 2005). The central argument from an ecological unequal exchange perspective is that the export of natural resources from LDCs to developed countries supports the consumption requirements of the latter at rates of exchange shaping the underdevelopment and environmental degradation within the former.

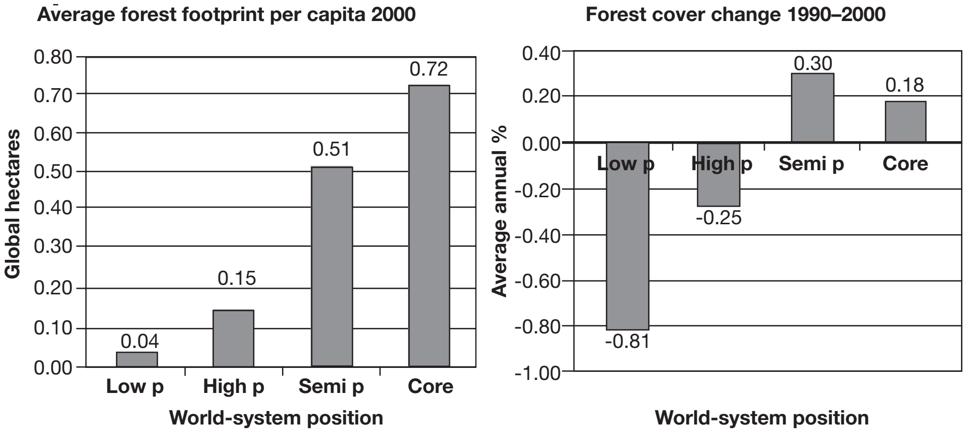
Environmental costs, in terms of disruptive human and ecological outcomes, are encountered during the extraction, production, and distribution of natural resources. Such costs are externalized to the extent that they are not reflected in the price received on the world market and are therefore borne by the exporting country.

The ecological implications of international trade can be difficult to conceptualize, however, as the global import-export of natural resources obscures responsibility for the ecological effects of production and consumption (Andersson and Lindroth, 2001). Trade lengthens the links between consumption and its consequences (Andersson and Lindroth, 2001).

Figure 2 highlights this paradox in relation to deforestation.[5] The average consumption of forest products in the core countries is .72 hectares per capita in 2000. This is 18 times the average per capita demand in low-periphery countries and approximately five times the demand within high-periphery countries. Despite the significantly greater consumption within both the core and semi-periphery, declining forest cover (deforestation) from 1990–2000 is the most pronounced in the low-periphery countries, an annual average loss of .81 percent, and the high-periphery, an annual average loss of .25 percent over the decade. Both the core and semi-periphery are characterized, on average, by reforestation from 1990–2000.

The forest consumption and cover change patterns presented in Figure 2 demonstrates that those countries with the lowest consumption of forest products experience the greatest rates of deforestation. Conversely, countries characterized by significantly greater demand for forest products are experiencing, on average, reforestation. Figure 2 highlights dynamics both within and between world-system positions. For example, deforestation is the highest in the periphery but

Figure 2 Average forest footprint and forest cover change by world-system position



Note: Low-P = low periphery; High-P = high-periphery; Semi-P = semi-periphery

it is unlikely that domestic forest product demand is the driving force; rather it is between position distributional processes shaped through international trade relations.

The consumption/environmental degradation paradox highlighted in Figure 2 may be partially explained through reference to greater capacity for reforestation, better governance of natural resource assets, and more efficient technology in core and semi-peripheral countries. Conversely, it may also reflect that economically dominant countries are able to maintain high rates of consumption of forest products by drawing upon the undervalued resources of LDCs, in turn shifting the environmental costs. Jorgenson (2006), for example, finds evidence that LDCs with relatively greater overall exports sent to more economically developed countries experience greater rates of deforestation from 1990–2000, net population, economic, state environmentalism, and other relevant variables. This research is significant because it establishes a direct link between the structure of international exchange and environmental transformation. In particular, the domestic attributes of the countries that LDCs trade with is relevant to considerations of deforestation within LDCs (Jorgenson, 2006).

Processes of environmental cost-shifting challenge prevailing conceptions that many industrialized countries are increasingly approximating 'environmental states.' Environmental states are those that are increasingly engaging in the 'institutionalization of environmental tasks in state policies and politics' (Mol and Buttel, 2002). The implication, in turn, is that such processes of institutionalization translate into real-world progress towards addressing economic-environmental problems.

The ecological modernization perspective, a theory increasingly prominent in environmental sociology, focuses upon the increasing embeddedness of ecological rationality in social practices and institutional developments, particularly within industrialized countries (Mol, 2002; Mol and Spaargaren, 2000). Moreover, the forces of globalization are argued to be crucial for the diffusion of ecological modern social organization and technology beyond the industrialized countries (Weidner, 2002).

The increasing capacity of industrialized countries to preserve their domestic environmental assets may, in part, be rooted less in greater environmental institutionalization and embrace of environmental rationality than in their ability to shift or displace the negative consequences of natural resource consumption. In contrast to a 'race to the bottom' in environmental standards worldwide, ecological unequal exchange suggests a polarization of environmental conditions or a 'stuck at the bottom' scenario in many LDCs (Muradian and Martinez-Alier, 2001a).

Appropriation of Environmental Space

Environmental space encompasses the stocks of natural resources and sink capacity or waste assimilation properties of ecological systems supporting human social organization.[6] It focuses upon the flows of materials, energy, and industrial waste between human societies and ecological systems through the chain of extraction, production, consumption, and disposal (Sachs, 1999). Ecological unequal exchange argues industrialized countries are increasingly appropriating both global natural resources and the sink capacity of ecological systems (Martinez-Alier, 2002). They are, in short, disproportionately utilizing global environmental space, constraining present and future utilization opportunities of LDCs.

The concept of environmental space recognizes that at any particular point in time renewable and non-renewable natural resources are theoretically, if not practically, limited (Daniels, 2002; Furst, 2001; OECD, 1997; Sachs et al., 1998). Improvements in technology and social organization can expand both the types of resources available and the productivity of existing resources over time (OECD, 1997; Opschoor, 1995). The concept, however, is generally intended to convey the argument that there are increasingly zero-sum dynamics between countries regarding access to natural resources and sink-capacity for externalization of industrial wastes.

Industrialized countries typically utilize relatively greater proportions of the sink-capacity of the global commons. Global warming, for example, is primarily a consequence of the carbon emissions of the core industrialized countries. Their use of fossil fuels threatens the assimilative capacity of the global environment and arguably precludes the ability of LDCs to follow a similar trajectory, within the confines of the global environment. Martinez-Alier (2002) suggests this imbalance is equivalent to a 'carbon debt' in which industrialized countries have utilized a disproportionate amount of environmental services without monetary payment or compensation (p. 229).

In terms of the supply of environmental resources, researchers have adopted materials flow analysis to chart the movement of natural resources by weight to evaluate the degree of export-import from the periphery, revealing that even as prices decline the movement of resources to the core generally continues to increase (Giljum and Eisenmenger, 2004; Giljum and Muradian, 2003; Muradian and Martinez-Alier, 2001a).

For example, the movement of non-renewable resources from LDCs, particularly minerals and fuels, increased dramatically between the mid-1970s and mid-1990s, even as prices declined (Muradian and Martinez-Alier, 2001a). Further, the import of semi-processed metals to industrialized countries has generally increased over the period (Muradian and Martinez-Alier, 2001b).

The cross-national appropriation of environmental space or biocapacity is not necessarily problematic, per se, unless it enhances the socioeconomic and environmental opportunities of some countries at the expense of others. Such zero-sum dynamics complicate the pursuit of intra-generational equity underlying the concept of sustainable development.

One measure of environmental space is the ecological footprint. It measures the biologically productive area required to support the consumption of renewable natural resources and assimilation of carbon dioxide waste products of a given population (Chambers et al., 2002; Wackernagel and Rees, 1996). It is a measure of societal demand upon not only domestic but also global natural resources. It is composed of six subcomponents: cropland, forest, grazing land, fisheries, energy, and built-up land. Calculation includes domestic resource production plus imports from abroad minus exports to other countries (Wackernagel et al., 2002). Because the ecological footprint measures demand for renewable natural resources relative to global biocapacity, it is a reasonable approximation of the per capita appropriation of environmental space of each country.

As measured by the ecological footprint, global demand for renewable natural resources exceeds biologically productive area by approximately 20 percent (Wackernagel et al., 2002). The world is thus characterized by ecological overshoot as demand outpaces the regenerative capacity of bioproductivity. Overshoot is manifested in the eventual depletion of natural capital stocks, as evidenced through deforestation, fisheries collapse, or atmospheric build-up of carbon dioxide, leading to prospects for global warming, and other large-scale ecological disturbances (Wackernagel et al., 2002).

Overshoot of biological capacity is maintained in the short term by drawing down or degrading natural capital faster than natural replacement rates. The global overshoot of demand relative to supply began in the 1980s and has been increasing steadily (Loh and Wackernagel, 2004). Global biocapacity changes with the amount of biologically productive area available and its average productivity (Loh and Wackernagel, 2004), but for nearly 20 years it has not changed as fast as consumption rates, despite greater efficiency of resource use or relative dematerialization in many core countries.

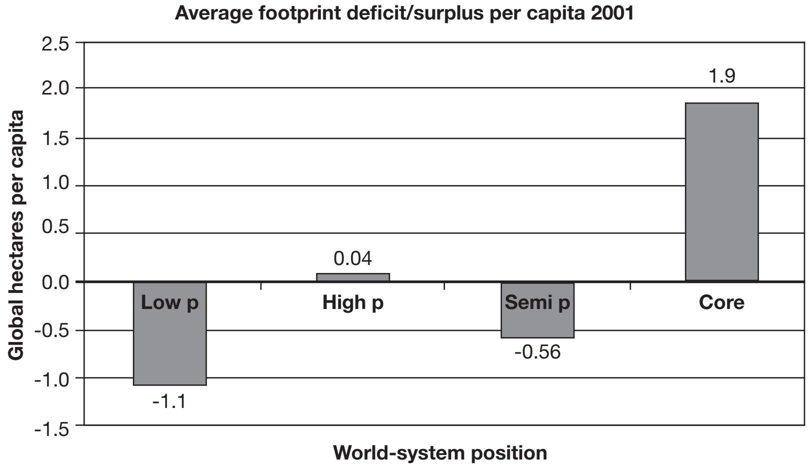
Many nation-states, particularly core-industrialized countries, have an ecological footprint greater than the natural capital stock available domestically. These countries are argued to be exhibiting an ecological deficit in that their use of bioproductive area must necessarily be appropriated from elsewhere. Countries run an ecological deficit because of high population density, high consumption rates, or both. The United States, for example, has an ecological footprint in 2000 of 9.6 hectares per person relative to a domestic biocapacity of 4.6 hectares (Venetoulis et al., 2004), arguably appropriating resources from other countries to meet consumption demands.

Figure 3 presents the average ecological deficit or surplus per capita by position in the world-system in 2001.[7] Core countries, on average, consume 1.9 hectares per capita more than are available domestically, running an ecological deficit. Conversely, low-periphery countries are characterized by an average ecological surplus of 1.1 hectares per capita, consuming much less than the biologically productive area originally located within their borders. Semi-peripheral countries are also characterized, on average, by an ecological surplus.

Much of the demand for renewable natural resources illustrated in Figure 3 is a consequence of the environmental consumption of the core countries. Population, affluence (GDP per capita), percentage of the population composed of nondependents (ages 15–65), and urbanization are the driving forces of national ecological footprint demand (York et al., 2003).[8] Political rights, civil liberties, and state environmentalism, variables drawn from ecological modernization theory, are not significantly related to national ecological footprint demand (York et al., 2003). Equally notable, research does not uncover an environmental Kuznets curve (EKC) or inverted-U relationship between either GDP per capita or urbanization and footprint consumption (York et al., 2003). There does not appear to be a decoupling, in absolute terms, of environmental demand relative to affluence or urbanization despite the fact that the core countries are also the most environmentally efficient per unit of economic output (York et al., 2003, 2005).

Further research using per capita ecological footprint demand reveals a strong causal relation between countries in the core of the world economy and higher footprint demand (Jorgenson, 2003). Utilizing path analysis, Jorgenson (2003) finds position in the core of the world economy is causally linked with the highest per capita footprints, followed by the semi-periphery and periphery. Beyond this direct effect, world-system position influences literacy rates and urbanization that, in turn, are positively correlated with per capita footprint consumption. Domestic income inequality is negatively correlated

Figure 3 Ecological footprint deficit/surplus per capita by world-system position



Note: Low-P = low periphery; High-P = high-periphery; Semi-P = semi-periphery

with footprint demand (Jorgenson, 2003). Subsequent research using slope dummy interaction terms to isolate within world-system position dynamics highlights that the positive effect of urbanization is more pronounced in the core, a consequence of extensive consumer markets and maintenance of the built infrastructure (Jorgenson, 2004).

Ecological unequal exchange suggests the patterns illustrated in Figure 3 reflect the fact that core countries utilize LDCs as resource taps in order to subsidize their own rates of material consumption, in the process arguably constraining resource consumption elsewhere. Jorgenson and Rice (2005), for example, find evidence LDCs with relatively greater trade with more economically powerful trading partners are characterized by lower per capita ecological footprints. This suggests that factors in addition to domestic economic development, population dynamics, and urbanization shape material consumption outcomes. In particular, structured trade relations among countries shape differential appropriation of environmental space.

The degree to which lower footprint consumption in LDCs translates into negative social welfare outcomes remains an empirical question. The ecological footprint measures resource demand but not human well-being directly. However, there is evidence that countries exhibiting lower per capita footprint consumption are characterized by higher levels of organic water pollution and, consequently, higher infant mortality rates (Jorgenson and Burns, 2004). Further, not all countries exhibiting a high footprint demand are characterized by high rates of social development but countries with low footprint demand are universally mired in poverty (Andersson and Lindroth, 2001).

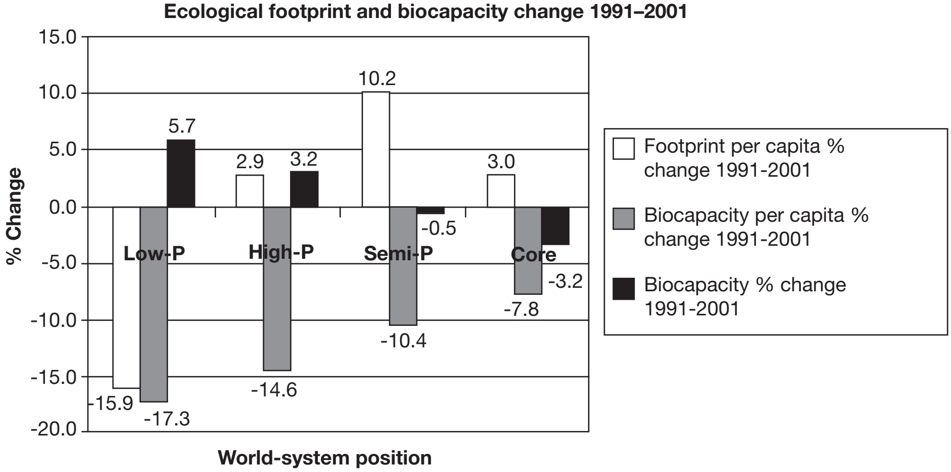
Arguably, poverty reduction and increasing social wellbeing is predicated upon greater consumption than characterizes many LDCs at present. The cross-national appropriation of environmental space or biocapacity within a context of global overshoot raises difficult questions about the trade-offs necessary to achieve broad-based sustainable development. If industrialized countries protect their domestic environments and satisfy their consumptive demands through reliance upon renewable and non-renewable resources from LDCs it may complicate equitable movement towards sustainable development and an acceptable standard of living in LDCs. This raises the difficult question of whether core countries need to reduce their consumptive demands in order for broad-based sustainable development to be a realistic option.

From 1961 to 1999 South Korea, for example, transitioned from a low to comparatively high ecological footprint demand subsequent with rapid industrialization (Wackernagel et al., 2004). In turn, domestic biocapacity declined by approximately 50 percent over this period and South Korea currently exhibits an ecological deficit whereby domestic consumption significantly outpaces domestic biocapacity (Wackernagel et al., 2004). South Korea's rise in footprint demand and decline in biocapacity, moreover, is only compensated for through a steep rise in imports of natural resources (Wackernagel et al., 2004). The degree to which other countries can follow a similar development trajectory remains an empirical question.

The uneven appropriation of environmental space, moreover, may be increasing over time. Figure 4 presents the average per capita biological capacity and ecological footprint change as well as total area of biocapacity change from 1991 to 2001 by world-system position.[9] Over the decade average per capita ecological footprint demand within low-periphery countries declined by 15.9 percent. Population growth is arguably a significant aspect of this decline, but declining footprint demand nevertheless raises questions regarding parallel processes of declining social welfare and food security in low-periphery countries. Conversely, high-periphery, semi-periphery, and core countries are characterized by increasing per capita footprint demand from 1991–2001. This effect is especially pronounced in semi-peripheral countries, a 10.2 percent average per capita increase.

Low-periphery countries also lost the greatest per capita amount of biocapacity, characterized by an average 17.3 percent decline. Within each of the world-system positions there is an average decline in biocapacity per capita. This suggests global population growth outpaces biocapacity growth. Further, it is unlikely high-periphery, semi-periphery, and core countries could increase their per capita footprint rates over the decade while simultaneously losing even greater amounts of domestic biocapacity without increasing their reliance upon the low-periphery as a resource tap, net increases in efficiency gains.

Figure 4 Ecological footprint and biocapacity change 1991–2001 by world-system position



Note: Low-P = low periphery; High-P = high-periphery; Semi-P = semi-periphery

Despite the per capita decline in biocapacity over the decade, low-periphery countries actually gained, on average, total biocapacity area as measured in 2001 relative to 1991, an increase of 5.7 percent. Arguably, all of this additional area is not actually consumed in low-periphery countries, as it is likely that some is destined for export elsewhere in the world-system. This result suggests population growth in low-periphery countries significantly outpaces biocapacity total area gains. High-periphery countries also gained total biocapacity area over the decade while semi-periphery and core countries lost total area. The decline in total and per capita biocapacity with both the semi-periphery and core in conjunction with increasing per capita footprint demand further suggests these countries increased their reliance upon natural resources originating elsewhere in the world-system.

Arguably there is more efficient utilization of natural resources within the core and semi-periphery wherein countries produce more for less (see York et al., 2005). But these efficiency gains appear relative and not absolute (York et al., 2005). Therefore, on average countries in the core and semi-periphery are becoming more efficient in utilizing environmental resources even as their absolute levels of natural resource throughput continue to increase. For example, research finds increasing cross-national per capita ecological footprint demand from 1991–2001 is driven by GDP per capita growth and growth in service-based economic activity, while manufacturing activity and export intensity are negatively correlated with footprint change (Jorgenson and Burns, forthcoming). This result is contrary to neoclassical economic suggestions concerning the environmentally beneficial relationship between economic growth and movement to service-based industries (Jorgenson et al., forthcoming). Rather, as core countries engage in economic growth and movement to service-based industries they may concurrently rely increasingly upon international trade in order to accomidate natural resource consumption requirements (Jorgenson et al., forthcoming).

Processes of Underdevelopment

Ecological unequal exchange encompasses more than simply uneven environmental cost-shifting and appropriation of environmental space. It is also conceptualized as a mechanism shaping the underdevelopment of resource-exporting LDCs (Bunker, 1985; Hornborg, 2001). Underdevelopment is characterized by a disadvantageous or peripheral position in the world-economy and the subsequent lack of economic leverage in exchange relations with other countries. Rather than lagging behind or simply needing to 'catch-up' with industrialized nations, the existence of underdeveloped countries helps facilitate the economic development of core countries in the first place (Frank, 1966).

Research suggests LDCs integrated into the global economy primarily through exports of natural resources exhibit slower economic growth (Atkinson and Hamilton, 2003; Auty, 1997, 2001; Gylfason, 2001; Sachs and Warner, 2001) and lower rates of physical, human, and natural capital development (Atkinson and Hamilton, 2003) relative to other developing countries. In the environmental economics and development literature this is now referred to as the 'resource curse hypothesis.' It is considered a 'paradoxical but seemingly robust' finding (Atkinson and Hamilton, 2003: 1793) and a 'reasonably solid fact' (Sachs and Warner, 2001: 837). It is paradoxical, from a neoclassical economics perspective, because resource abundant economies should possess comparative advantages enhancing economic welfare relative to otherwise identical resource-poor countries. Natural wealth should promote short-run economic growth and long-term domestic investment in other productive assets, including physical and human capital, that promote sustainable future income levels (Atkinson and Hamilton, 2003).

If sustainability is defined as a development path along which per capita welfare is non-declining (see, for example, Pezzey, 1989), than resource-rich LDCs should be well on their way towards such outcomes. That they are generally moving in the opposite direction has prompted environmental economists to question whether the rent or profits from resource endowments are being sufficiently reinvested in other forms of physical and human capital to insure a non-negative accumulation of a range of societal assets or wealth over time. Explanations generally focus upon distorted domestic natural resource, public expenditure, and macroeconomic policies within the affected countries. Such explanations are notable, but primarily for what is left unconsidered – the exogenous factors shaping the historical trajectory of developing countries reliant upon natural resource exports.

The Netherlands Fallacy

Ecological unequal exchange points to the geographic, temporal, and cultural discontinuities between consumption and the environmental side effects or consequences of consumption related behavior, analogous to the idea of the 'Netherlands Fallacy.' The Netherlands Fallacy is based upon the observation that the Dutch population and their average standard of living are only made possible through reliance upon imported resources (Ehrlich and Ehrlich, 1990). Therefore, the Dutch population is not self-sufficient and is arguably overpopulated relative to domestic environmental capacity (Ehrlich and Ehrlich, 1990). It is a mistake in reasoning, a fallacy in other words, to fail to appreciate that the Netherlands must draw upon the resources of other countries to support their aggregate population and its associated consumption patterns (Ehrlich and Ehrlich, 1990).

Over time the Netherlands Fallacy has also come to suggest that domestic environmental conditions are not necessarily an accurate reflection of the environmental burdens engendered by domestic standards of living and rates of material consumption. A key lesson is that any particular country's environmental fate, positive or negative, is not simply the consequence of domestic factors but also its structured relations with other countries. The negative consequences of one country's environmental demands may be borne by others. This has also been referred to as the 'rich-country-illusion effect' (Andersson and Lindroth, 2001: 120). By importing natural resources and exporting sink capacity demand and environmental costs inhabitants of core countries can mistakenly perceive their lifestyles as sustainable, as their consumption rates are not tightly linked to domestic environmental conditions (Andersson and Lindroth, 2001). Conversely, the rich-country-illusion effect implies that LDCs are to blame for failure to sustain their domestic natural capital (Andersson and Lindroth, 2001).

The Netherlands Fallacy is a reminder that to conceptualize consumption related dynamics in a globalizing world it is increasingly important to examine zero-sum relations among countries and the socioeconomic and environmental costs and benefits that are differentially incurred. To assume the Netherlands, for example, supports a population with a relatively high standard of living within a context of relative environmental abundance is to fail to consider the 'bigger picture.' Ecological unequal exchange hints at what that picture might look like.

Summing Up the Theory of Ecological Unequal Exchange

Ecological unequal exchange is characterized by the objectively asymmetric transfer of value embodied in the productive potential of energy and natural resources (Hornborg, 2003). Such transfers, however, are only possible through the illusions of normatively neutral exchange through market mechanisms, misconstrued as reciprocal exchange between economically unbalanced partners (Hornborg, 2001). Market prices, therefore, are a crucial mechanism through which the core appropriates ecological value and exports waste to the periphery (Hornborg, 2001).

An ecological oriented focus upon the uneven processes underlying capital accumulation supplements rather than replaces the traditional Marxist concern with labor exploitation (Bunker, 1985; Hornborg, 2001, 2003). Although the environment is transformed through labor exploitation (Moore, 2000), we argue it is a mistake to conflate both labor and ecological exploitation.

Capital accumulation is fundamentally rooted in alteration of ecological systems and the exploitation of labor (Bunker, 1985; Hornborg, 2001). It shapes both the social relations of production and the form and integrity of ecological systems. Conflation of both types of unequal exchange obscures analysis of the thermodynamic or energetic basis of industrial capitalism and the systemic flows of energy and natural resources underlying the socioeconomic metabolism of the world-system. Further, it neglects the recognition that raw materials and energy are essential components underlying the transformative basis of industrial production (Bunker, 1985).

Value, therefore, is appropriated not only through labor but the acquisition of undervalued energy and natural resources (Bunker, 1985). This transfer is recognizable in biophysical terms but hidden through exclusive reference to monetary indicators, a consequence of the neoclassical economics tendency to equate exchange value with utility. This transfer of value cannot be calculated solely in terms of wages, prices, and profit (Bunker, 1985). Ecological unequal exchange, therefore, can only be conceptualized by recognizing that exchange value and use value do not necessarily coincide (Hornborg, 1992).

3. CONCLUSION

We have elaborated upon the theory of ecological unequal exchange, a perspective relevant to the consideration of the political-economic structures shaping the interaction of human societies and ecological systems. This perspective points to the increasingly globalized structural relationships underpinning the accumulation of capital and forging distinctive cross-national burdens and benefits regarding ecological use and degradation. International trade, a material expression of the international division of labor and commodity production, shapes ecological dynamics in a systemically recognizable manner. Such dynamics transcend the overly simple domestic economic growth-environmental degradation dichotomy. Rather, global environmental change is also conditioned by the interdependence and interaction among countries, forcing consideration of the environmental transformations and patterns of resource use and degradation/preservation between the core, semi-periphery, and periphery of the world-system.

Ecological unequal exchange provides a framework for conceptualizing how the socioeconomic metabolism or material throughput of industrialized countries may negatively impact more marginalized countries in the global economy. It highlights the cross-national uneven flow of energy and natural resources reinforcing disparities in production and material consumption. This inequitable appropriation of natural capital shapes both per capita affluence and poverty across the divide between developed and developing societies. Economically and militarily powerful countries are advantageously situated within the world economy and appropriate a disproportionate share of both renewable and non-renewable natural resources as well as shift the environmental costs of their production-consumption-accumulation activities. This is not only complicit in driving increasing environmental demand overall but linked to the diminishing opportunities of LDCs to achieve socioeconomic stability and domestic ecological protection. The problem is neither wealth nor poverty alone but their complex interrelationship at the global level.

To illustrate the environmental cost-shifting dimension of ecological unequal exchange we examined cross-national data on forest products demand in 2000 and forest cover change 1990–2000. The data reveal core and semi-periphery countries are, on average, characterized by significantly greater per capita demand for forest products, and yet it is countries in the periphery that experienced the greatest loss of forest cover from 1990–2000.

To highlight the environmental space dimension underlying ecological unequal exchange we evaluated environmental demand relative to world-system position. Core countries consume more natural resources than are available domestically, on average, exhibiting an overall ecological deficit while countries located elsewhere in the world-system typically use fewer resources than are available domestically. This pattern is significant given the global consumption of renewable natural resources currently overshoots available biocapacity (Loh and Wackernagel, 2004). It suggests core countries may be promoting the unsustainable utilization of global environmental resources, rather than at the forefront of sustainability dynamics as suggested by the environmental state literature within the ecological modernization perspective. Further, data also reveal that from 1991–2001 per capita demand for renewable natural resources in low-periphery countries declined substantially. Despite reduced consumption, they nonetheless are also characterized by the greatest per capita loss of biocapacity over this period. Other segments of the world-system are characterized by increasing per capita environmental demand over the period.

These trends are not consistent with pursuit of broad-based sustainable development. Rather, they appear to characterize a type of asymmetrical sustainable development that, in the long term, appears logically inconsistent. Core countries, in other words, attain high consumption rates of natural resources and maintain their domestic environmental assets at the expense of countries more marginally situated within the world-system. Core countries, therefore, appear sustainable while simultaneously making true broad-based sustainable development increasingly problematic.

Future research efforts are needed to more clearly articulate the mechanisms underlying ecological unequal exchange dynamics. One area of inquiry could involve the examination of governance structures in LDCs as a possible mediating variable shaping unequal exchange outcomes. Second, the unequal exchange dynamics LDCs encounter may vary according to the type of natural resources exported. Finally, additional dependent variable measures examining issues of international political economy in ecological terms need to be investigated to further conceptualize the challenges between consumption, equity, and unsustainable structural relationships within the global economy.

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NOTES

1 In this article LDCs and the 'periphery' refer to countries typically categorized by world-systems researchers as occupying the most marginalized structural positions in the global economy, recognizing these boundaries are somewhat malleable across various scholars. Reference to industrialized and 'developed' countries refers to countries typically categorized as core or semi-peripheral. See Appendix A for one example of a more precise delineation of this tripartite system.

2 Our focus is upon international trade relations. In addition, there are important dynamics related to foreign direct investment and the cross-national movement of hazardous production processes that are beyond the scope of this article. See, for example, Frey (2003).

3 Our definition and elaboration is drawn from numerous sources, many of which do not necessarily incorporate this label. It is a broad synthesis of varying, but we argue, congruent processes.

4 Heavier weighted arrows signify more significant negative processes of unequal exchange.

5 Forest footprint is a calculation of total wood, wood fibre, and pulp consumption (excluding fuelwood). A global hectare is one hectare of biologically productive space adjusted for world average productivity. Data are from Venetoulis et al. (2004). Forest cover change data are from the United Nations Food and Agriculture Organization publication, *State of the World's Forests* (2003). A negative value represents deforestation over the period while a positive value represents reforestation. Analysis is based upon the 126 countries with data available on both variables and that have at least four percent of their total land area in forest cover, to avoid anomalies related to forest cover processes in desert countries. Core designation is based upon Smith and White (1992). Semi-periphery designation is based upon relative consensus across several network analysis studies (Nemeth and Smith, 1985; Smith and White,

1992; Snyder and Kick, 1979). To examine variation within the periphery, we rank ordered countries by GDP per capita and then split the sample approximately in half to produce high and low peripheral designations. See Appendix A for specific designations.

6 This concept is also referred to as 'environmental utilization space' (OECD, 1997), 'environmental capacity' (McLaren, 2003), and 'eco-space' (Opschoor, 1995).

7 Data are from Loh and Wackernagel (2004). Calculated by: total per capita footprint demand – total per capita domestic biocapacity. Biocapacity refers to usable biologically productive area. Negative numbers represent an ecological surplus. Positive numbers represent an ecological deficit. Analysis is based upon countries listed in Appendix A.

8 York et al. (2003) use the total national ecological footprint score (per capita footprint multiplied by total population). This allows them to assess the independent contribution of population.

9 Per capita footprint and biocapacity data are from Loh and Wackernagel (2004). Total biocapacity change represents total area percent change in 2001 relative to 1991. Data are from the National Footprint and Biocapacity Accounts (2004) by the Global Footprint Network [www.footprintnetwork.org]. Analysis is based upon countries listed in Appendix A.

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APPENDIX

Countries by world-system position (*N* = 148)

Core (*N*=11)

Belgium/Luxembourg[1]
Canada[1]
France[1]
Germany[1]
Italy[1]
Japan[1]
Netherlands[1]
Sweden[1]
Switzerland[1]
United Kingdom[1]
United States[1]

Semi-periphery (*N*=21)

Argentina[1]
Australia[1]
Austria[1]
Brazil[1]
China[1]
Czech Rep.[1]
Denmark[1]
Finland[1]
Greece[1]
India[1]
Ireland[1]
Israel[1]
Korea, South[1]
Mexico[1]
New Zealand[1]
Norway[1]
Poland[1]
Portugal[1]
Russian Federation[1]
Spain[1]
Venezuela[1]

High-periphery (*N*=60)

Albania[1]
Algeria
Belarus[1]
Belize[1]
Bosnia-Herzegovina[1]
Botswana[1]
Bulgaria[1]
Chile[1]
Colombia[1]
Costa Rica[1]
Croatia[1]
Cuba[1]
Dominican Rep.[1]
Ecuador[1]
Egypt
El Salvador[1]
Estonia[1]
Gabon[1]
Guatemala[1]
Hungary[1]
Indonesia[1]
Iran[1]
Iraq
Jamaica[1]
Jordan
Kazakhstan[1]
Korea, North[1]
Kuwait
Latvia[1]
Lebanon
Liberia[1]
Libya
Lithuania[1]
Macedonia, FYR
Malaysia[1]
Mauritius[1]
Morocco[1]
Namibia[13]
Panama[1]
Paraguay[1]
Peru[1]
Philippines[1]
Romania[1]
Saudi Arabia
Serbia-Montenegro
Slovakia[1]
Slovenia[1]
South Africa, Rep.[1]
Sri Lanka[1]
Swaziland[1]
Syria
Thailand[1]
Trinidad and Tobago[1]
Tunisia
Turkey[1]
Turkmenistan[1]
Ukraine[1]
United Arab Emirates
Uruguay[1]
Zimbabwe[1]

Low-periphery (*N*=56)

Afghanistan
Angola[1]
Armenia[1]
Azerbaijan[1]
Bangladesh[1]
Benin[1]
Bolivia[1]
Burkina Faso[1]
Burundi
Cambodia[1]
Cameroon[1]
Central African Rep.[1]
Chad[1]
Congo[1]
Congo, Dem. Rep.[1]
Côte d'Ivoire[1]
Eritrea[1]
Ethiopia[1]
Gambia[1]
Georgia[1]
Ghana[1]
Guinea[1]
Guinea-Bissau[1]
Haiti
Honduras[1]
Kenya[1]
Kyrgyzstan[1]
Lao, PDR[1]
Lesotho
Madagascar[1]
Malawi[1]
Mali[1]
Mauritania
Moldova, Rep.[1]
Mongolia[1]
Mozambique[1]
Myanmar[1]
Nepal[1]
Nicaragua[1]
Niger
Nigeria[1]
Pakistan
Papua New Guinea[1]
Rwanda[1]
Senegal[1]
Sierra Leone[1]
Somalia[1]
Sudan[1]
Tajikistan
Tanzania[1]
Togo[1]
Uganda[1]
Uzbekistan[1]
Vietnam[1]
Yemen
Zambia[1]

1 = Countries included in the analysis reported in Figure 2.

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