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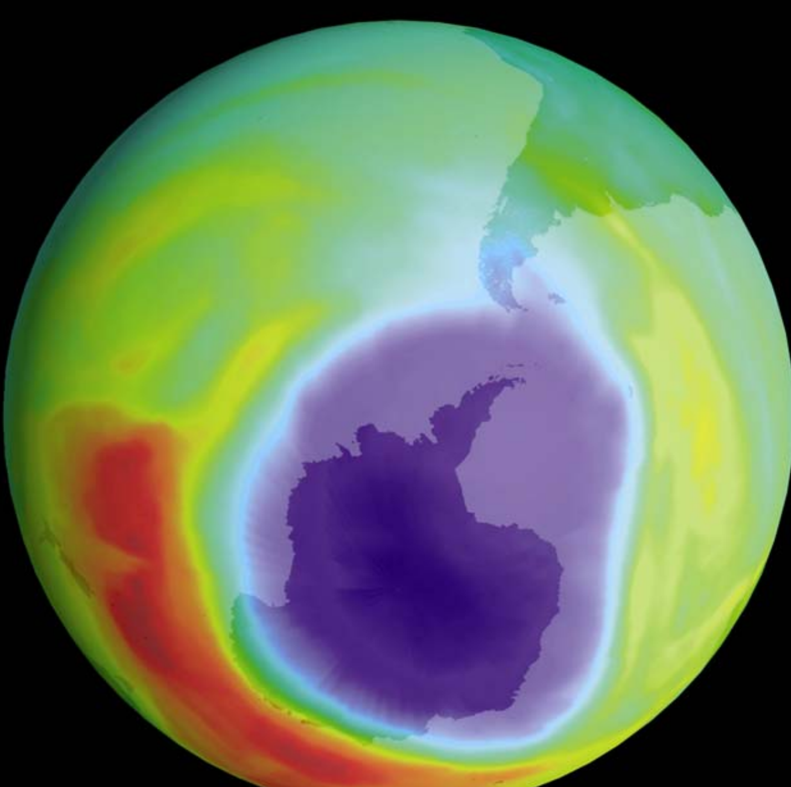

special issue

GLOBALIZATION AND THE ENVIRONMENT

Edited by Edward Kick & Andrew Jorgenson

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The main editorial goal of the *Journal of World-Systems Research* is to develop and disseminate scholarly research on topics that are relevant to the analysis of world-systems. We especially want to include works that proceed from several different theoretical stances and disciplines. These include, but are not limited to, civilizationists, evolutionary approaches, international political economy, comparative, historical and cultural analysis. We seek the work of political scientists, historians, sociologists, ethnographers, archaeologists, economists and geographers.

We especially encourage works that take theory seriously by confronting problems of conceptualization and making definitions of concepts explicit, by formulating hypotheses, constructing axiomatic theories and causal models. Theoretical research programs that combine theory construction with comparative research are badly needed to take the world-systems approach beyond the stage of a perspective.

We also want to encourage the application of comparative, quantititave and network-analytic methods to world-systems research, though we will certainly also publish pieces that do not use these methods. Any empirical study that is deemed relevant to world-systems analysis may be published even if it uses a very different conceptual framework.

And finally we also want to publish discussions of future trajectories and options for the modern world-system and considerations of what can be done to create a more humane, peaceful and just world society.

The Purposes of JWSR are

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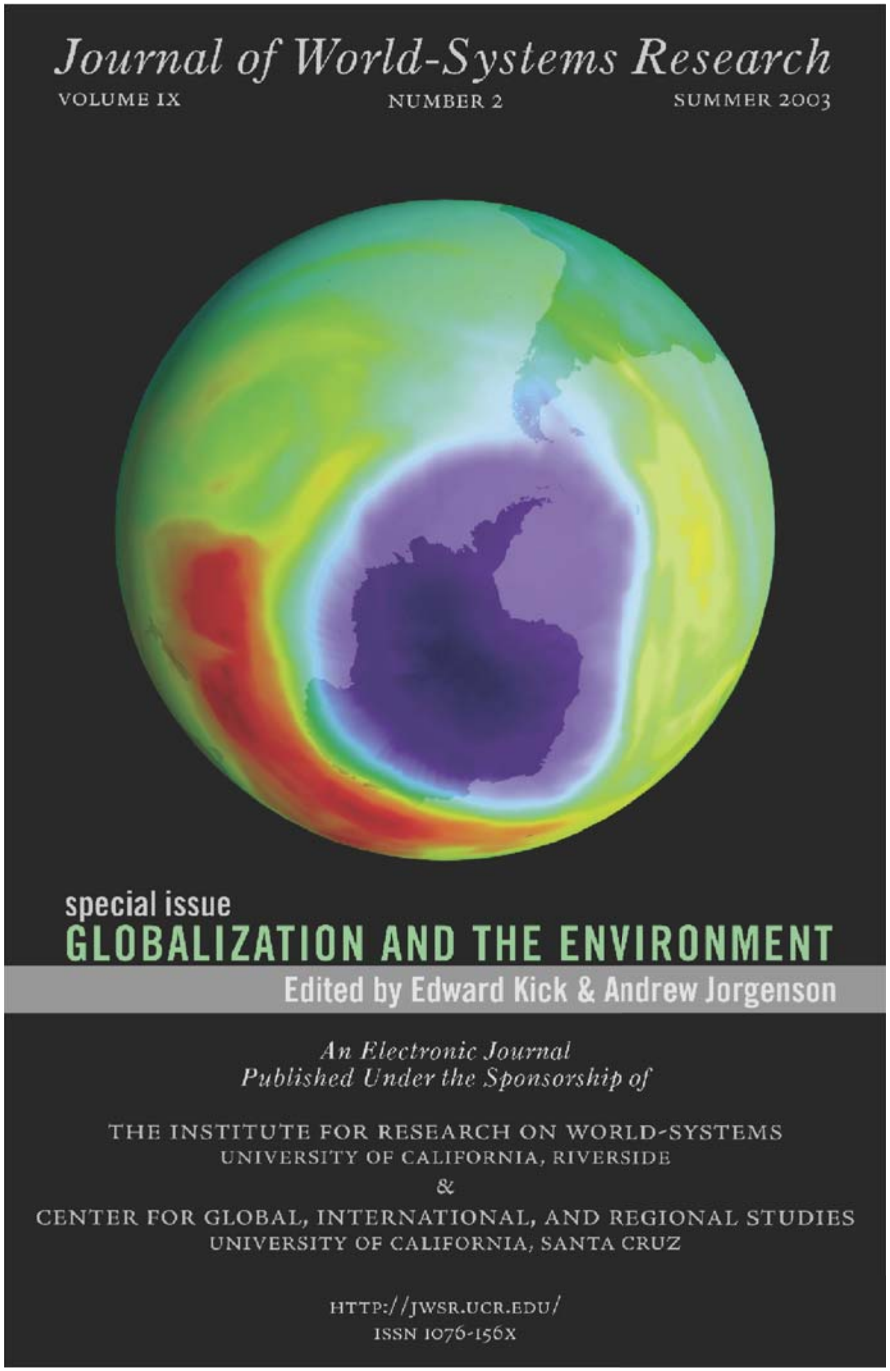

Globalization and the Environment

Andrew K. Jorgenson
Edward L. Kick

Human societies have long experienced the increasingly rapid expansion of the modern world-economy, an economy that has existed since at least the middle 1400s, meeting crisis after crisis in accumulation (e.g. Abu-Lughod 1989; Arrighi 1994; Chase-Dunn 1998; Chase-Dunn and Hall 1997; Chew 2001; Frank 1978, 1998; Frank and Gills 1993; Kentor 2000; Moore 2003; Pomeranz 2000; Wallerstein 1974, 1979). Rapid technological growth has been part and parcel of this expansion that has tightened the global division of labor and importance of distant events for all humans. This division of labor permits further expansion in rationalized production, and it reaches everywhere to expand markets and offer up cheap labor and material resources to increase surplus value (e.g. Marx 1906; see also Foster 1999, 2002; Harvey 1999).

In recent decades, global capitalist economics, technology (including communication), and global military reach have worked together to remove a major political-military, economic and ideological challenge to capitalism, that is, Eastern bloc-style socialism (it could be argued that we now are working on the next challenge, Islam). While these dynamics have stunted any nascent challenges to market expansion, the latter has created other contradictions. One of these is that "globalization" now threatens the human race with environmental disasters (e.g. Broswimmer 2002; Foster 2002; Grimes 1999).

Generally lacking in the environmental literature, as well as the globalization literature, is a mature long-term historical approach that explains the emergence

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of such dynamics. Fortunately, this is provided in a world-systems approach. Indeed, the last two decades have witnessed a burgeoning area of inquiry in the social sciences that blends environmental sociology with the world-systems perspective. This is quite evident in the vast array of relevant conferences and related publications.[1] Recent conferences include the twenty-first annual conference of the Political Economy of the World-System section (PEWS) of the American Sociological Association (ASA), titled "Ecology and the World-System" (1997, University of California, Santa Cruz); the PEWS and Environment and Technology ASA sections (co-sponsors) 2001 conference titled "Globalization and the Environment: Prospect and Perils" (Anaheim, California); and the international symposium on "World-System History and Global Environmental Change" (2003, University of Lund, Sweden).

There is a general consensus in this blossoming, multidisciplinary literature that the capitalist world-economy is in crisis because it cannot find solutions to key dilemmas including the inability to contain ecological destruction[2] (e.g. Broswimmer 2002; Bunker 1985; Foster 1999, 2002; Grimes 1999; Hornborg 2001; Jorgenson 2003; Jorgenson and Burns 2003; Wallerstein 1999). Global modes of production and accumulation are intimately linked to environmental degradation (e.g. extraction of natural resources and multiple forms of pollution via commodity production). Furthermore, the core-periphery model of exploitation provides useful, historically grounded explanations of different environmental and ecological outcomes (e.g. Bergesen and Parisi 1997; Kick et al. 1996; Moore 2003; Roberts and Grimes 2002; Smith 1994), and degradation can be seen as both a cause and consequence of underdevelopment in non-core regions (Boswell and Chase-Dunn 2000:143–144; Bunker 1985; Burns, Kentor, and Jorgenson 2003; Chase-Dunn and Hall 1997; Evans 1979; Jorgenson and Burns 2003).

Social scientists and others commonly label processes of social change in the modern world-economy as falling under the rubric of globalization. Moreover, "globalization" continues to be a buzzword in political discourses that employ ideas about global integration and competition to justify actions and inter-

[1] For a review of recent publications in this area, see Jorgenson (2003), Jorgenson and Burns (2003), Bergesen and Bartley (2000), or the literature review sections for the articles appearing in this special issue.

[2] Ecological modernization theory represents an alternative perspective that foresees the twenty-first century as a time of ecological modernization and the re-rationalization of societies into more ecologically sustainable forms (Humphry, Lewis, and Buttel 2002:166–171; see also Mol and Sonnenfeld 2000a, 2000b).

related policies (e.g. McMichael 2000; Shiva 2002; Stiglitz 2002), while social scientists working in the world-systems tradition have scientifically defined (and empirically charted) structural globalization as being composed of different inter-related dimensions of broadening and deepening interaction networks—especially political, economic and cultural globalization (e.g. Chase-Dunn and Hall 1997; Chase-Dunn 1999; Chase-Dunn, Kawano, and Brewer 2000; Chase-Dunn, Jorgenson, Reifer et al. 2002; see also Kick 1987; Kick et al. 1995; Snyder and Kick 1979). We reject the notion that these dimensions constitute different aspects of social reality that should be studied separately by various theoretical perspectives or academic disciplines. Instead we contend that it is useful to distinguish between them in order to understand how they have affected one another. Furthermore, they reflect structural factors and political-economic processes in the world-economy that impact the well being of human and non-human populations in different zones of the world-system as well as regional ecologies and the global biosphere.

Globalization is not new analytically or empirically. Those working in the world-systems tradition have addressed analogous long-term historical cycles, trends, transformations, and other factors in the capitalist world-economy since the perspective's inception decades ago. The articles appearing in this issue reflect recent empirical and theoretical developments of the structural world-systems approach to globalization and how the increasing scale and intensity of systemic processes in the capitalist world-economy impact the natural environment and living conditions of human populations.

This special issue begins with the article "Cornucopia or Zero-Sum Game? The Epistemology of Sustainability." Author Alf Hornborg systematically contrasts opposing general perspectives on economic development and concomitant ecological degradation. The first perspective is the traditional neoclassical model in economics, which has been employed in dominant areas of discourse regarding further economic development as the long-term solution to environmental problems. The second perspective is the zero-sum world-systems approach that models environmental destruction in more peripheral regions as an outcome of economic developments in core areas of the world-economy. Hornborg provides a heavy-handed critique of the faulty logic and unrealistic view of the former perspective and its inability to adequately explain the unequal impact of core-based production and consumption on the natural environment in different regions of the world-system. His critical discussion and positive emphasis on the latter perspective sets the stage for the empirical analyses in subsequent articles.

In the second article, "Matter, Space, Energy, and Political-Economy: The Amazon in the World-System," Stephen Bunker argues that it is absolutely necessary to analyze the material processes of production in space as differentiated by hydrology, climate, topography, and distance between relevant places. This approach would significantly increase our understanding of the expansion and intensification of the social and material relations of capitalism that have created and sustain the dynamic growth of the world-system from the local to the global. Drawing from his extensive research of the Amazon Basin, Bunker discusses the spatio-material configurations that structured local impacts on global formations from within this region. In so doing, he offers critiques of the tendencies in the globalization and world-systems literature to apply spatial metaphors without investigating how space affects the material processes around which social actors organize the political-economy. More importantly, through this analysis Bunker shows that the 400 year-long sequence of extractive economies in the Amazon has reflected the shifting demands of industrial production headquartered in core regions. This thorough study illustrates how such processes can be more accurately understood by focusing on spatio-material configurations of local extraction, transport, and production.

The third article, "Exporting the Greenhouse: Foreign Capital Penetration and CO_2 Emissions 1980–1996," consists of a quantitative cross-national analysis of less-developed countries in which Peter Grimes and Jeffrey Kentor examine the impacts of foreign investment dependence on carbon dioxide emissions. Their most striking finding is the significant positive effect of foreign capital penetration, coupled with the weak and non-significant effect of domestic investment on CO_2 emissions. Grimes and Kentor suggest that transnational corporations relocate more environmentally unfriendly production to countries with relatively less environmental controls. This claim is further supported by the previous research of Timmons Roberts (1996), which indicates that semiperipheral and peripheral countries are less likely to participate in international environmental treaties. Moreover, according to Grimes and Kentor foreign investment in less-developed countries is more likely to be concentrated in industries that use relatively higher levels of energy consumption; power generation techniques employed in foreign capital dependent countries are likely to be less energy efficient; and with the ever increasing expansion of global production, the transport of inputs and outputs is relatively more energy intensive in non-core countries with poorer infrastructures.

In a related selection titled "Social Roots of Environmental Change: A World-Systems Analysis of Carbon Dioxide Emissions," Timmons Roberts, Peter Grimes, and Jodie Manale employ cross-sectional and lagged OLS regression techniques to a sample of 154 countries and examine the impacts of a country's world-system position, domestic class, and political factors on a nation's carbon dioxide intensity. This outcome variable is related to that of Grimes and Kentor's study, but rather than studying absolute levels of emissions, Roberts, Grimes, and Manale examine the amount of carbon dioxide released per unit of economic output. Their findings indicate a Kuznets distribution of carbon dioxide intensity in relation to world-economy position. More specifically, the relatively least efficient consumers of fossil fuels appear to be countries falling within the upper periphery and semiperiphery. Moreover, semiperipheral and peripheral countries with relatively higher levels of debt, higher levels of military expenditures, more repressive political infrastructures, and larger export-oriented economies tend to be the least efficient consumers of fossil fuels. Even with a differently measured indicator of emissions, these findings coincide rather well with those of Grimes and Kentor. Countries in the semiperiphery and upper periphery also tend to be those experiencing relatively higher levels of foreign capital dependence.

R. Scott Frey then offers an in-depth case study of the Maquiladoras located on the Mexican side of the US-Mexico border. In his article, "The Transfer of Core-Based Hazardous Production to the Export Processing Zones of the Periphery: the Maquiladora Centers of Northern Mexico," Frey systematically describes how core-based transnational corporations externalize environmental and ecological degradation resulting from production processes to peripheral regions, a process which has continually increased through the broadening and deepening of material production in the world-economy. Moreover, Frey provides evidence that illustrates how these environmental outcomes adversely impact the quality of life for the already exploited human populations living in regions surrounding the Maquiladora centers. Like the preceding articles, Frey provides strong evidence of the impacts of structural globalization on the environment and well-being of communities located outside of core regions in the world-economy.

Following Frey, Thomas Burns, Edward Kick, and Byron Davis use multivariate regression analysis to test the effects of social and demographic causes of deforestation across different zones of the world-system. A rather noteworthy contribution of their article "Theorizing and Rethinking Linkages between the Natural Environment and the Modern World-System: Deforestation in the Late 20^{th} Century" is the application of a methodology (slope-dummies) that allows for a more thorough empirical analysis of how social factors and environmental outcomes operate differently across zones of the world-economy. This method is a more sophisticated and useful approach to modeling non-linear relationships in cross-national studies that test world-systems propositions. Unlike previous studies that focus on earlier decades, Burns, Kick, and Davis find that deforestation has become more pronounced in peripheral regions of the world during 1990–2000 as opposed to the semiperiphery. In addition to differences in social factors between the periphery and semiperiphery, Burns, Kick, and Davis suggest that this increase in deforestation in the periphery is also a function of "recursive exploitation" in which a nation in the semiperiphery is at a disadvantage to one in the core, yet is able to work exchanges in its favor when they involve peripheral countires.

Lastly, in a review essay titled "Lateral Pressure and Deforestation," Andrew Jorgenson provides a thorough critique of Corey Lofdahl's recently published book *Environmental Impacts of Globalization and Trade: A Systems Study*. Jorgenson points out some striking weaknesses in the book, especially its literature review and under-specified empirical models. However, he applauds Lofdahl for his application of geo-modeling to cross-national and global analyses of environmental outcomes and his development of a new quantitative measure of trade connectivity as a predictor of deforestation in less-developed countries. Jorgenson emphatically suggests that other social scientists should follow Lofdahl's lead with the use of GIS in analogous empirical studies and the incorporation of his newly constructed indicator into more specified models of deforestation and other environmental outcomes.

We would like to thank all contributing authors and the entire editorial staff of the *Journal of World-Systems Research* for helping to make this special issue possible. We hope that these articles—both individually and collectively—will lead to a better understanding of how the capitalist world-economy impacts the global ecological system, and assist in the development and implementation of more informed international policies and practices that will reduce the negative impacts of production and accumulation on the biosphere and human populations living throughout the world, particularly in non-core regions.

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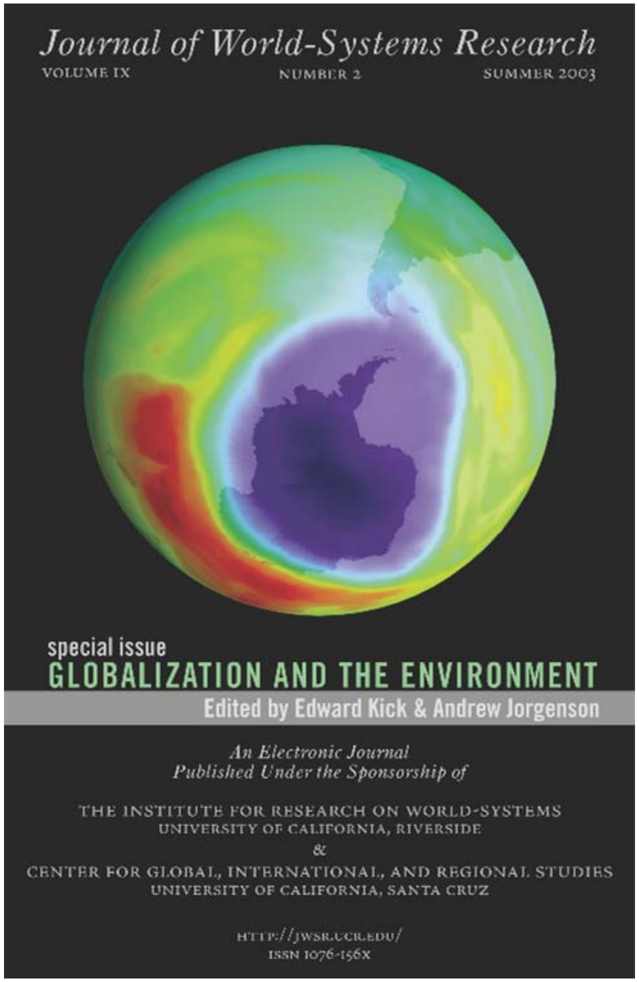

ABSTRACT

This article contrasts two fundamentally different understandings of economic growth and "development" that lead to diametrically opposed approaches to how to deal with global ecological deterioration. One is the currently hegemonic perspective of neoclassical economic theory, which has been used to advocate growth as a remedy for environmental problems. The other is the zero-sum perspective of world-system theory, which instead suggests that growth involves a displacement of ecological problems to peripheral sectors of the world-economy. The article begins by sketching the history of these two perspectives in recent decades and reflecting on the ideological and epistemological contexts of their appearance and different degrees of success. It then turns to the main task of critically scrutinizing some of the foundations of the neoclassical approach to environmental issues, arguing that its optimistic view of growth is based on faulty logic and a poor understanding of the global, physical realities within which money and the capitalist world-system operate.

Cornucopia or Zero-Sum Game? The Epistemology of Sustainability*

Alf Hornborg

INTRODUCTION

On the very first days of the new millennium, newspapers in Sweden—as elsewhere—devoted some editorial space to assessing the state of the world. The leading daily *Dagens Nyheter* expressed puzzlement over a survey showing that a large percentage of Swedish youth were not particularly optimistic about the future. Why this worry about global ecology, the editor asked, now that the pessimistic prophecies of the Club of Rome could be dismissed once and for all? Yet, the previous day, in the same newspaper, an environmental journalist had observed that the state of the world environment is considerably worse than most people in the richer countries realize. The problem, he said, is that these people can choose to stay ignorant about the South's environment simply by switching television channels. Here were thus two very different messages on global ecology offered in the same newspaper.

Similarly contradictory were its assessments of global inequality. On New Year's Eve, an editorial proclaimed that the Marxist notion that the affluence of the rich is based on other people's impoverishment could be decisively dismissed. In the very same issue of *Dagens Nyheter*, however, an entry with the heading

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* I would like to thank Rowman & Littlefield Publishers for permission to reprint this text, originally published as chapter 2 in my book *The Power of the Machine: Global Inequalities of Economy, Technology, and Environment*, AltaMira Press, 2001 (see http://www.altamirapress.com/).

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"Renaissance for Marx" reports that a new biography of Karl Marx is the season's bestseller in Britain. The next day, there is a two-page interview with the Marxist sociologist Manuel Castells, introduced as "the hottest intellectual in the world," who perceives the present as characterized by a process of unprecedented social polarization and warns that the conflict may soon become critical. How are we to understand these schizophrenic messages on global environment and development that surround us as we enter the third millennium?

Judging from mainstream public discourse, faith in technology and economic growth seems stronger than ever. The WCED conference in Rio de Janeiro in 1992—the climax of three decades of negotiations on global issues—solidified an official creed suggesting that growth is the general solution to environmental problems (World Commission on Environment and Development 1987). The key concept, of course, became "sustainable development." This creed is now often referred to as "ecological modernization" (Hajer 1995). Meanwhile, however, there remains a widespread countercurrent of skepticism, passive and invisible for the most part, but remarkably powerful when demonstrating strength enough to overturn the important World Trade Organization (WTO) meeting in Seattle on the eve of the old millennium. Many people must be asking themselves today if the critics in the 1970s were really so completely wrong about the conflict between growth and environment, and if WCED's interpretation of global issues is really the only one possible. The 1970s saw a widespread concern that the economic growth of industrial sectors occurred at the expense of the Third World and the global environment. According to the WCED paradigm, however, growth is of benefit for both the global economy *and* global ecology. We may refer to the two paradigms as "zero-sum game" versus "cornucopia" theories of growth.

It might seem as if the choice between zero-sum game and cornucopia models should be a simple empirical question. What do the data say? It no longer seems feasible, however, to identify "simple empirical" questions in the social sciences. The global interconnections are too complex. The opposite camp generally seems to be able to turn each specific piece of information inside out by putting it in a different context and approaching it from a different perspective.

In a book the subtitle of which is *Measuring the Real State of the World*, Danish statistician Björn Lomborg (2001) contradicts Worldwatch Institute, Greenpeace, and the World Wide Fund for Nature by suggesting that what have been perceived as global problems of inequality and environmental deterioration are mostly illusions. One by one, he dismisses all our worries about resource depletion, per capita food production, increasing gaps between rich and poor, deforestation, acidification, species extinction, chemical pollution, and global warming. The conclusion that not just some of but *all* these worries are illusory is

indeed remarkable. It is obvious that both the compilation and the interpretation of statistics to a large extent boil down to whether we *wish* to see this or that pattern. This is not a simple question of manipulation, but of a fundamental human desire to see verified by data the patterns we imagine to exist in the world. But how do we choose these patterns or interpretations to begin with?

To the extent that we do *choose* our models, it is evident that our considerations are not concerned solely with the criterion of credibility. We like to think that our most fundamental criterion for "truth" is whether a specific interpretation of causal connections can explain the most aspects of our global predicament, but the widespread paradigm shift that has occurred since the 1970s instead suggests that a more crucial consideration is which interpretation *we can live with*. In the industrialized nations in the 1960s and early 1970s, there was an existential space, so to speak, for radical criticism. Especially among younger people, there was a widespread faith in the capacity of collective, social movements to transform fundamental structures in society. When faith in the future and collective change withered in the mid-1970s, a great many people in the North probably found the idea that their affluence was based on the impoverishment of the South and the global environment unbearable and thus impossible to accept. An important factor underlying this shift was the increasing mobility of globalized capital. Faced with the threat of unemployment, local populations everywhere grew more careful in their criticism of power (cf. Bauman 1998). To the extent that some of the indignation over environmental problems and global inequality persisted, it was generally transformed from revolutionary fervor to resignation. Globalization thus implied contradictory impulses that condemned both the embittered in the South and the conscience-stricken in the North to a predicament of perpetual, cognitive dissonance. Through media they came into ever-closer contact with global inequalities, while at the same time it seemed increasingly evident to them that there was virtually nothing they could do about them.

This may explain some of the market for the new genre of "green-bashing," counter-environmentalist books like Lomborg's. Many readers probably felt comfortable with Lomborg's wholesale denial of environmental concern. But there are more subtle ways of disarming indignation than simple denial. What ecological modernization has achieved is a neutralization of the formerly widespread intuition that industrial growth is at odds with global ecology. The environmental concern of young people is now being redirected into special educational establishments designed to promote the message that the adverse effects of economic growth can best be amended with more growth. The discursive shift since the 1970s has been geared to disengaging concerns about environment and development from the criticism of industrial capitalism as such. But the central question about capitalism should be the same now as it was in the days of Marx: Is the growth of capital of benefit to everybody, or only to a few at the expense of others? However much contemporary debate tries to sweep this question under the carpet, it will continue to reappear, albeit in new forms. Since Marx's time, it has been extended primarily in two directions. On one hand, questions of injustice and unequal exchange have transcended the local relation between worker and capitalist and been applied to the global exchange between industrial centers and their peripheries; on the other hand, there have been attempts to include global ecology in the same analysis.

Judging from much contemporary public discourse, asking questions about unequal exchange would seem obsolete or irrelevant for today's world. Concepts like "imperialism" and "exploitation" have well-nigh vanished in the *sustainababble* following the Rio conference. Yet, Marx's basic intuitions seem impossible to eradicate, however hard the neo-liberal discourse of the 1980s and 1990s has tried. Björn Hettne (1990) shows how thinking about global development has oscillated through the past century. In the mid-twentieth century, the dominant paradigm was based on a Eurocentric concept of modernization that, through the work of Walt Rostow and others, translated global inequality into a temporal axis that defined the future for the "underdeveloped" countries. "Development aid" was viewed as a global, Keynesian welfare policy that in the end would be of benefit both to the poor and to the rich. In the 1970s, the dependency theory of Gunder Frank, Samir Amin, and others gained prominence in connection with demands for a "New Economic World Order" and the success of the Organization of Petroleum Exporting Countries (OPEC) in bargaining oil prices. It argued for a kind of zero-sum perspective, in which the affluence of the "metropolis" or "core" was to be understood as based on the impoverishment of the "satellite" or "periphery." In the 1980s, however, a neo-liberal "counterrevolution" swept away both Keynesianism and dreams of a new world order. Milton Friedman, the World Bank, and the International Monetary Fund (IMF) redefined poverty as mismanagement and opened the world to an even tougher brand of capitalism. In 1990, Hettne believed that a new counterpoint may have been emerging in the form of "anti-modern" and marginalized groups such as environmental movements, feminists, peasants, indigenous peoples, and the unemployed. In the decade that followed, however, the most publicized criticism of unfettered capitalism came from multimillionaire George Soros, who expressed deep worries about the omnipotence of money and the growing vulnerability of globalized capitalism. Nevertheless, by the end of the decade, it seemed that Hettne's prediction was perhaps being substantiated by the globalized, motley alliance of anticapitalist demonstrators who captured the headlines in Seattle.

THE ZERO-SUM PERSPECTIVE: FAILURES AND PROSPECTS

It is valid to ask why dependency theory has lost so much of its former influence in development studies. Was it because the development strategy it inspired—isolationism—proved such a failure? Hettne (1990) reminds us that the attempts of Chile and Nicaragua at "de-linking" were soon countered by measures from more powerful nations aiming at "destabilization" of these deviants. Meanwhile, the Newly Industrialized Countries of southern Asia were rewarded for their opportunism and willingness to submit to the conditions of global capital. Instead of dismissing dependency theory, we might refer to Wallerstein's (1974) observation that "development" is to advance from periphery to semiperiphery. Conversely, we can understand the current "underdevelopment" of major parts of the former Soviet Union as a process of peripheralization. Seen in this perspective, development and underdevelopment are the results of movements of capital in the world system, and the shifts of affluence in the 1980s and 1990s can be seen as a confirmation not of the recommendations of dependency theory but of its fundamental, zero-sum model. There is evidently an inclination to dismiss the theoretical understanding of the dynamics of the world system—like the Marxist perspective as such—as soon as the practical implications someone has derived from it prove a failure. This is tragic, because it should be quite feasible to arrive at a correct analysis of a problem without (yet) having developed a good solution.

Brewer (1990) lists several major types of criticism that have been directed at dependency theory. According to Brewer, the argument that core areas have a "monopoly" and that they "exploit" their peripheries does not include explicit, theoretical definitions of these concepts, but rather amounts to tautology. It is particularly problematic that the theory does not define a central concept like "surplus" or explain in which ways metropolis-satellite relations are to be seen as projected in geographical space. Brewer argues that nations are not really relevant entities in this context. He also criticizes dependency theory for not being able to explain why certain countries seem to be able to break free from their dependency.

The critics are right in that there is an element of tautology in dependency theory as long as the "core" or "metropolis" is defined as the place where accumulation occurs, while "accumulation" is defined as what occurs in the core. There are, however, more substantial specifications, such as the focus of the Prebisch-Singer theorem on the structural logic of exchange relations between industrial sectors and those sectors that deliver their raw materials. It is nevertheless true that the concept of "surplus"—that which is transferred from periphery to core—is not defined in a clear manner. For more or less self-sufficient subsistence economies, Paul Baran (1957) offered a simple definition of "surplus" as the difference between what is produced and what is consumed, but for societies engaged in production for the market, it is necessary to refer to some measure other than money (market prices) to be able to argue that a particular exchange is exploitative. To solve this problem and produce a more rigorous argument, dependency theory could build on concepts from the natural sciences such as energy (see below).

Brewer is also right in that nations are not relevant units, simply because core-periphery relations cannot in any but the crudest manner be represented in terms of spatially demarcated areas. Gunder Frank (Frank 1966) instead argued that they were to be conceptualized as polarizing exchange relations at different levels of scale both within and between countries. These polarized flows can be traced even in local contexts such as the exchange between a hacienda owner and his workers. This geographical indeterminacy has been accentuated by the increasing globalization of capital flows, which make it all the more difficult to identify the "core" as a spatially distinct social unit or actor. There is no necessary congruity between the spaces where the appropriated resources are accumulated, where the capitalists live, and where they have their bank accounts.

Yet capital continues to generate obvious spatial patterns, as anyone can see on nightly satellite photos. Such images lend concrete, visual support, for instance, to statistics which say that the average American consumes 330 times more energy than the average Ethiopian. When new parts of the world system succeed in attracting capital—that is, when they "develop"—it shows clearly in the satellite images, as in the strong contrast between the dark northern and luminous southern half of the Korean peninsula. It must be of relevance to world system theory that the United States' share of world energy consumption is 25%, while 20% of the world's people do not have access to enough energy to successfully maintain their own body metabolism. This obviously also has an environmental dimension. The richest 20% of the world's population consume 86% of the aluminium, 81% of the paper, 80% of the iron, and 76% of the lumber (Brown 1995). Per capita carbon dioxide emissions in 1990 were around five tons in the United States but only 0.1 tons in India. (Remarkably, however, many people in the industrialized North continue to believe that it is their mission to educate people in the South on how to live and produce sustainably, as if the North was setting a good example, and as if environmental problems in the South were the result of ignorance rather than impoverishment.)

If rates of energy dissipation are an essential component in the inequitable dynamics of the world system, it must be a central theoretical challenge to integrate perspectives from the social and natural sciences to achieve a more

complete understanding of capital accumulation. An explicit attempt to connect dependency theory and energy flows is Stephen Bunker's (1985) study of underdevelopment in the Amazon. He shows how the "extractive" economies of peripheral Amazonia are at a systematic disadvantage in their exchange with the "productive" economies of industrialized sectors. The flows of energy and materials from the former to the latter tend to reduce complexity and power in the hinterland while augmenting complexity and power in the core. Extractive economies generally cannot count on a cumulative development of infrastructure as can the productive economies in the core, because economic activities in the former are dispersed and shifting according to the location of the extracted materials. As the stocks of natural resources become increasingly difficult to extract as they are depleted, an intensification of extraction will tend also to increase costs per unit of extracted resources, instead of yielding the economies of scale associated with intensification in the industrial core. Bunker's analysis suffers from his inclination to view energy as a measure of economic value (cf. Hornborg 2001), but in other respects his underlying intuition is valid. 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. Environmental quality is thus also an issue of inequitable global distribution. "Environmental justice" is merely an aspect of the more general problem of justice within the framework of world system theory.

THE CORNUCOPIA MODEL: IS GROWTH REALLY GOOD FOR THE ENVIRONMENT?

The preceding arguments to me seem logically coherent, credible, and persuasive. I am thus all the more curious about the alternative interpretation—what I refer to as the "cornucopia" model, that is, the currently hegemonic worldview that declares capital accumulation in the core completely innocent with regard to poverty and environmental problems in the South. An unusually accessible and instructive example of this worldview comes from Swedish economist Marian Radetzki (1990, 1992), whose essays address the overarching question of whether there is a positive or negative correlation between economic growth and environmental quality. He observes that the worst environmental destruction occurs in the poor rather than the richer countries and concludes from this that environmental quality improves as the economy grows and becomes "denser." The explanation, says Radetzki, is that the intensity of environmental damage decreases as per capita GNP increases. This intensity is defined as the quantity of "environmental resources" that are expended to generate one unit of GNP. Intensity of environmental wear is reduced because with growth there is a tendency for "material intensive" production to be replaced by the production of services. Meanwhile, there is an increase in the willingness of consumers to pay for a clean environment the more affluent they become, and environmental policies in wealthier nations encourage the development of new environmental technologies. Instead of intensifying the consumption of "environmental utilities," these nations can substitute services from "human and physical capital" for those of natural resources. For this reason, forests and other natural resources are *not* diminishing in the industrialized countries. Instead, much of the landscape is reverting to something approaching a "natural state." Growth and technological development make it possible to invest, for example, in aquaculture instead of depleting wild fish stocks, plantations instead of cutting down rain forests, and swimming pools instead of exploiting natural beaches. Radetzki concludes that it is thus possible to maintain continued economic growth, and that there is in fact an *unlimited* potential for "sustainable growth."

Radetzki's texts are useful reading because they summarize, in a nutshell, the logic of an economist's approach to the relation between growth and environment in a way that makes it very clear how the basic assumptions of the cornucopia model differ from those of the zero-sum game model. An essential difference is evidently Radetzki's assumption that an economic activity and its environmental consequences coincide geographically. If environmental quality is relatively high where growth is high (and vice versa), he concludes that growth reduces environmental damage, instead of (or perhaps without hesitating at?) the equally feasible interpretation that the environmental consequences of growth have been *shifted* to other parts of the world system. It is in fact unclear if Radetzki discusses the "environment" as a local or a global phenomenon. It seems unlikely that he would consider it a *solution* to environmental problems to have them shifted to someone else's backyard, but some of his arguments leave it an open matter. He writes, for instance, that growth makes it feasible to legislate so as to increase production costs for polluting industries, which has led to "a considerable shift of environmentally damaging activities from richer countries to poorer, where costly environmental policies are absent" (Radetzki 1990: 8–39; my translation). "The environment," he continues, "is to a very large extent a concern of the wealthy." It is to be noted that this reasoning is offered in a context where he argues for growth as a solution to environmental problems. If we assume that Radetzki is

not advocating a continued shifting of pollution to poorer countries, as at least one prominent World Bank economist[1] actually has done, we must draw the conclusion that his vision of the future is that all people in the world shall be "wealthy." This strikes me as impossibly naïve, considering that the gap between rich and poor continues to widen. Between 1947 and 1987, the ratio of per capita income between the richest and the poorest countries increased from 50:1 to 130:1 (Adams 1993).

Not only is the growth recipe in a global perspective politically naïve, but it also disregards the fundamental objection that processes of resource depletion and environmental destruction will increase with wealth, after all, even if they are shifted to other locations and thus vanish from sight. We have already mentioned emissions of carbon dioxide, which are 50 times higher for the average American than for the average citizen of India. Mathis Wackernagel and his colleagues have estimated that if all the people in the world were to reach the same standard of living as that in the richest countries, they would require three additional Earths (Wackernagel and Rees 1996; Wackernagel et al. 1997). Although the global access to "ecoproductive" land decreased from 5 to 1.7 hectares per capita between 1900 and 1990, the per capita "footprints" of the richer countries increased from 1 to between 4 and 6 hectares (Wackernagel et al. 1997). To accumulate money is ultimately to be able to increase one's claims on other people's resources. It is evident that these claims cannot increase indefinitely, because the resources are not unlimited.

When Radetzki argues that there is a positive connection between economic growth and environmental quality, we must ask what this connection looks like. Does growth simply dissolve environmental problems as such (and not just locally), or does it shift them to poorer areas? Again and again we are inclined to interpose the crucial question: "*Where?*" Where is environmental quality improved? Where is it realistic to build artificial micro-environments (such as swimming pools) that reduce wear on the local environment, and where are the natural resources procured with which to build them? Where can the landscape revert to a "natural state," and from where are the resources appropriated that substitute for its former yields?

Two fundamental objections can be directed at Radetzki's argument, both of which concern the capacity of the market and monetary measures to con-

[1] On December 12, 1991, World bank chief economist Lawrence Summers, using inpeccable economic arguments, suggested that the World Bank should be encouraging a migration of "dirty" industries to less developed countries.

ceal other dimensions of economic processes. When he claims that intensity of resource use decreases as per capita GNP increases, we may forget that whereas resource use is a physical reality, GNP is "only" a symbolic reality. GNP is ultimately a measure of the terms of trade (world market prices) that a country has been able to secure for its products and services in exchange for those of other countries. GNP is thus a measure that reflects a country's position in socially negotiated, global exchange relations. Rather than say that intensity of resource use decreases per unit of GNP per capita, we can just as well say that the prices of a nation's products increase faster than its resource use. This could be understood as an expression of increasing margins of profit in industrial sectors as a consequence of increasingly advantageous terms of trade *vis-à-vis* the raw materials sectors. To conclude, from what Radetzki says about the relation between resource consumption and GNP, that growth is good for the environment would be tantamount to saying that it does not matter if environmental damage increases, as long as GNP increases *faster*. But the crucial question, of course, should be whether environmental damage increases in *absolute* terms.

The second objection can be directed at the claim that growth and technological development make it possible to substitute the services of "human and physical capital" for those of nature. The issue boils down to what we mean by "substitute." From a local perspective it might appear possible to "substitute" labor and capital for land; this approach became fundamental to industrial society from the very start. But to the (large) extent that these extra inputs of labor and technology are made possible by utilizing natural resources from another part of the world system (e.g., by importing food for the labor force or fossil fuels for the machines), it is questionable if it is valid to claim that labor and capital really can "substitute" for land. From a global and physical perspective it is to a very large extent an illusion that the stocks of natural resources can be increased with the help of more labor and capital. The faith in "substitution" shows the extent to which economic science has emerged as a local (originally British) perspective that really does not ask questions about the global management of resources beyond the territory of the individual nation.

As long as the primary knowledge interest of a science is to generate growth strategies for individual companies or nations, it is only natural that its fundamental assumptions should differ from those required of a science of global resource management. Only when the world is viewed as a finite and in certain respects closed system are we able to discover that what is locally perceived as a cornucopia may in fact be a component in a global zero-sum game. This discovery must be allowed to shake the very foundations of the two centuries-old assumptions of economics. We must finally ask ourselves whose knowledge interests our research is to serve: the individual corporation, the individual nation, or all of humanity?

To build an understanding of global interconnections between ecology and economy that serves the knowledge interests of global resource management and environmental justice, rather than national or corporate growth, we need to reconceptualize several aspects of development theory. Instead of visualizing nations as autonomous territories the environmental condition of which reflects, in a simple and immediate way, their own economic activities, we must learn to think of the world as a *system*, in which one country's environmental problems may be the flip side of another country's growth. Those of us who live in the privileged, affluent core would be amiss to use our green forests and fertile fields as evidence that worries about global ecology are unfounded, because the liberation and recovery of previously impoverished landscapes to a large extent has been made feasible by the import of resources from peripheral areas both within and between nations. The most difficult but perhaps also most important point is to learn to view technological development as an expression of capital accumulation, and thus ultimately of unequal relations of exchange with less "developed" sectors of world society. Growth and technological development in some parts of the world system are thus organically linked to underdevelopment and environmental deterioration in others. If we want to work for global, environmental justice, we first need to develop a new theoretical understanding of technology as a redistribution of resources made invisible by the vocabulary and ideology of the market. This unequal exchange of resources can be made visible only by identifying, beneath the flows of monetary exchange value, measures of real resources such as energy, labor time, and hectares of productive land.

I am inclined to think that our preparedness to abandon the "cornucopia" model of growth and technology for a "zero-sum game" perspective will be connected to wider, existential concerns. It would probably be naïve to think that a majority of people in the wealthier nations, out of a pure quest for truth and solidarity with the distant and anonymous masses of the South, would choose an interpretation of reality that could be expected to subject them to deep and continuous, ethical conflict. Perhaps their affluence would first have to be seriously jeopardized in order for such a paradigm shift to occur at any substantial scale. Above all, we may assume that the zero-sum game perspective will be acceptable only if accompanied by a concrete and attractive vision of how the fundamental logic of capital accumulation can be transformed or domesticated in the name of global solidarity. For a large part of the twentieth century, the Marxist worldview offered *one* such vision that attracted a substantial part of humanity. Very few would today deny that that vision was incomplete and misguided in several respects. If we were to endeavor a new vision, it would probably have to proceed further in its questioning not only of the market, but of even more fundamental, modern institutions such as money and technology. To domesticate the market, a long-term aim might be to split it horizontally so as to render local subsistence and global communication two parallel but distinct and incommensurable domains. Changes in that direction could amount to an immunization of local ecosystems and human life-worlds *vis-à-vis* the ravages of global capital flows. This would also serve to restrain the unevenly distributed growth of technological infrastructure, so that the machinery of the wealthier nations does not continue to expand at the expense of the very life-space of the global poor.

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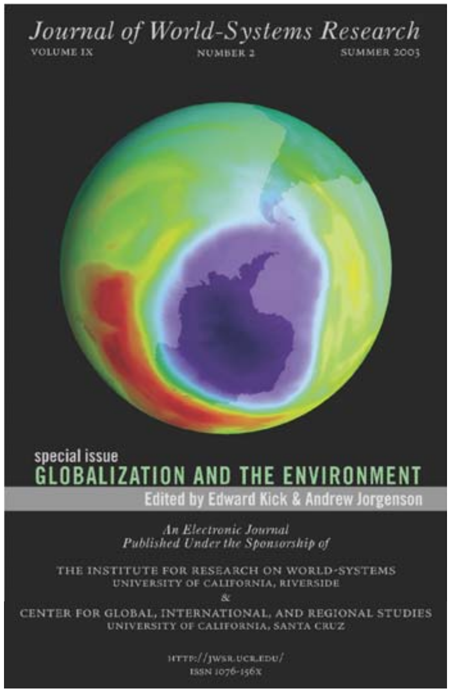

ABSTRACT

Many authors have attempted to incorporate the local into the global. World-systems analysis, though, is rooted in processes of production, and all production remains profoundly local. Understanding the expansion and intensification of the social and material relations of capitalism that have created and sustain the dynamic growth of the world-system from the local to the global requires analysis of material processes of natural and social production in space as differentiated by topography, hydrology, climate, and absolute distance between places. In this article, I consider some of the spatio-material configurations that have structured local effects on global formations within a single region, the Amazon Basin. I first detail and criticize the tendency in world system and globalization analysis, and in the modern social sciences generally, to use spatial metaphors without examining how space affects the material processes around which social actors organize economy and polity. I next examine the work of some earlier social scientists who analyzed specific materio-spatial configurations as these structured human social, economic, and political activities and organization, searching for possible theoretical or methodological tools for building from local to global analysis. I then review some recent analyses of spatio-material determinants of social and economic organization in the Amazon Basin. Finally, I show that the 400-year-long sequence of extractive economies in the Amazon reflected the changing demands of expanded industrial production in the core, and how such processes can best be understood by focusing our analysis on spatio-material configurations of local extraction, transport, and production. The Amazon is but one of the specific environments that have supplied raw materials to changing global markets, but close consideration of how its material and spatial attributes shaped the global economy provides insights into the ways other local systems affect the world-system.

Matter, Space, Energy, and Political Economy: The Amazon in the World-System

Stephen G. Bunker

INTRODUCTION

Incorporating the local into the global in analytically compatible ways poses a major challenge for scholars of both world-systems and globalization (Chase-Dunn, 2000, Tomich, 2001, Robinson, 2001). Most of these authors have attempted to incorporate the local into the global. World-systems analysis, though, is rooted in processes of production, and all production remains profoundly local. Instead of searching for the local in the global, I propose to examine the ways that the local—and particularly as manifest in the materio-spatial features of production—structures and organizes the world-system. Understanding the expansion and intensification of the social and material relations of capitalism that have created and sustain the dynamic growth of the world-system requires analysis of material processes of natural and social production in space. Examining the effects of the local on the global requires that we consider space as materially differentiated by topography, hydrology, climate, and absolute distance between places. In this article, I suggest some steps toward this goal by considering materio-spatial configurations that have structured local effects on global formations within a single, topographically, hydrologically, and geologically distinct, region, the Amazon Basin.

I first detail the tendency in world systems and globalization analysis, and in the modern social sciences generally, to use spatial metaphors to bound or contextualize social processes without considering the effects of space as it impinges on the material processes around which social actors organize economy and

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polity. I then examine the work of some earlier social scientists who analyzed specific materio-spatial configurations as these structured human social, economic, and political activities and organization. I consider the theoretical and methodological tools these scholars provide for the task of building analysis from local detail into global system.

I next review some recent analyses of materio-spatial effects on social and economic organization in the Amazon Basin, the largest, most complex tropical rain forest in the world and—historically and currently—a significant source of raw materials critical for world industry. Finally, I show how some of the lessons provided by the local configurations of space and matter in the Amazon have informed my colleagues' and my efforts to discover and explain mechanisms that drive the secular material intensification and spatial expansion of the world-system.

I conclude by considering materio-spatial effects of social-environmental interactions that have driven and been driven by expanded reproduction of capital. Industrial production has accelerated consumption of raw materials and thus increased the absolute space across which ever larger volumes and more numerous types of matter are transported. I demonstrate that globalization—identified as a recent or novel phenomenon by Sklair (2000) and others—is in fact the latest phase of materio-spatial expansion and intensification that emerges from technical innovations. States, firms, and sectors collaborate technically, financially, and politically to develop and implement these technologies, and this collaboration generates episodic incidents of dramatic increases in economies of scale, in industrial production, in raw material extraction, and in transport.

Technological and organizational economies of scale drive the expanded reproduction of capital; the increased absolute space across which the increasing volumes of matter consumed must be transported raises unit costs. The contradiction between economies of scale and the cost of space creates a tension out of which cost-reducing, scale-dependent innovation and organization of transport emerge. I attempt to show that these processes: (1) drive the spatial expansion of raw materials markets, and thereby (2) stimulate development of progressively cheaper, faster technologies and more extensive infrastructure for their transport, and thus, (3) drive the globalization of the world economy. I will argue that globalization can best be understood by focusing our analysis on the secular expansion and intensification of materio-spatial configurations of local extraction, transport, and production.[1]

1. Even transport, the movement of matter through space, is at each moment as local as the location of the vehicle and of the capital sunk in the built environment at each point in the space traversed.

SPACE AND NATURE IN MODERN SOCIAL SCIENTIFIC ANALYSIS

World-systems analysts use spatial terms—core, periphery, world, global—as a conceptually central organizing metaphor, but they seldom elaborate the most fundamental mechanisms and processes that expand and intensify the social and material relations of capitalism to the entire globe. This oversight is peculiar, given the strong explanations in economic theories, Marxian and classical, of mechanisms that favor agglomeration or spatial concentration of industial production. The primary reason for progressive spatial dispersion of production is that the expanded reproduction of capital creates the need for greater volumes of a greater variety of raw materials. Varied topographic, hydrological, geological, and atmospheric conditions are needed to produce all of these different types of matter.

All of this matter is naturally produced in distinct local places. Space is simultaneously a means and a condition of its production and an obstacle or cost for its transport. The vast array of raw materials consumed in expanding industrial production is therefore dispersed among multiple ecologically different locations. Industrial economies expand materially while agglomerating spatially. Accelerated depletion of the most proximate sources of each type of raw material enhances the need for seeking sources across expanded space created by increased consumption. Expanding industrial economies must therefore procure raw materials across ever greater spaces and distances. Increasing costs of distance generate incentives for states, firms, and finance to develop more efficient means—technological and infrastructural—of transport. The successive campaigns and strategies of nations striving to dominate world trade—the Portuguese, the Dutch, the British, the United States, and the Japanese—have each superceded the then-established capacities to procure and transport cheaply over great distance the raw materials they used in greatest volume. The cumulative effects of these technological and infrastructural increases have progressively globablized the world economy.

Technological and social organizational innovations to reduce the inputs needed per unit of production and to reduce the unit costs of transport[2] thus reiterate (cf. Haydu, 1998) and surpass (cf. Arrighi, 1994) the sequentially cumulative power and scale of earlier solutions to the contradiction between scale and space. Each solution depends on expanded technical economies of scale. Each scale increase accelerates the depletion of proximate sources of raw material and drives the procurement of new sources at greater distance. Each such episode

2. Unit costs of transport can be calculated by ton/mile, that is weight/distance.

thus perpetuates and exacerbates the cycle of contradiction between economies of scale and the cost of space.

The contradiction between scale and space is constant, but each solution to it is rooted in the the intersection of (1) the geography, demography, political and financial organization of the economically expanding nation and (2) the technological innovations that drive its economic growth with (3) the materio-spatial characteristics of the raw materials that these new technologies require. The reiterated solutions to this contradiction can only succeed in each instance if they take topographic, spatial, and material properties of local production into account.

The scale of the contradiction increases with each systemic cycle of accumulation (cf. Arrighi, 1994). Each solution therefore tends to be scale dependent (Bunker and Ciccantell, 2001). The reiterated solutions are thus sequentially cumulative; that is, each separate solution is distinct in the characteristics of its technological innovation and the sources of its raw materials; but the scale of its technology and the distance to its raw materials accumulate sequentially. The reiterated, cumulatively sequential, but materio-spatially distinct, solutions to the contradiction between scale and space constitute a central mechanism behind the expansion and intensification of the world system. In other words, the local—in all of its natural diversity—significantly drives the global towards its apparent social homogeneity.

Analysts of the world-system and of globalization have overlooked the contradiction between scale and space and have thus ignored its dynamic consequences. In this they follow more general trends in the social sciences. Over the past half century, social scientists have tended to consider space as the passive context, container, or boundary of social organization and activity. Space conceived thus is neither analyzed nor theorized.

To the extent that modern geographers attempt to analyze or theorize space, they tend to emphasize the social construction of space. Neil Smith (1984) for example, incorporates Schmidt's notions of second nature into Harvey's (1983) discussions of the built environment to declare that the dynamic of capital leads to a social reconstruction of nature, including of space. He interprets Marx's statement, that time annihilates space, within a generalized vision that capital recreates nature and time. Smith's subsequent critique of renewed attention to the early Marxist writings of Wittfogel betrays the extent to which geography's unhappy battle against the excesses of environmental determinism and geopolitical analysis continues to constrain radical geographers' attention to the natural characteristics and effects of space on society. Lefevbre's (1991) and Soja's (1985, 1989) oversocialized views of space manifest a similarly dogmatic rejection of any consideration of what Smith calls absolute, or natural, space. Even though David

Harvey (1983) has to address the material characteristics of space when he elaborates Marx's theories of differential rent, his explanations for the incorporation of new space into economic expansion rest completely on notions of the overaccumulation and site-specific devaluation of capital, thus ignoring the lessons about material and space in both Marx and von Thunen.

MATERIO-SPATIAL CONFIGURATIONS IN EARLIER SOCIAL SCIENTIFIC THOUGHT

Earlier social scientific traditions took the material effects of space on economy far more seriously. Wittfogel ([1929]1985) was not alone in his attention to the materio-spatial logic of hydrology and topography. In the first half of the last century, descriptive economic historians such as Richard Albion (1926) or Harold Innis (1956) analyzed specific local extractive economies by (1) the material attributes of topography, geology, hydrology, and climate that produced the resource extracted, and (2) the topographic and hydrological characteristics of the space between the locus of extraction and the locus of consumption as these characteristics affected the technology and the cost of transport across this distance. Innis and Albion both used materio-spatial analyses in ways that contributed to explanations of how and why efforts of dominant groups in Europe structured the conquest, settlement, exploitation, and struggles over the territories incorporated into European imperialist systems.

For Albion, both shipbuilding and metallurgy in Britain were constrained by the location, accessibility, and transport cost of timber.[3] The course of navigable rivers and the location of soils and climates conducive to the growth of different tree species determined the location and organization of these economically and politically critical industries. As growing demand for iron and for ships overshot the domestic supply of oak for charcoal and for timbers, these same considerations influenced the imperial strategies of a British state enormously sensitive to Admiralty needs for ships and cannon.

Albion showed that the material features—masts, keel, hull planks, rudder, or caulk and tar—of different kinds of ship required the strengths, flexibilities, shapes, saps, and sizes particular to various species of tree that grew in specific climates, soils, and elevations. Albion used these materio-spatial details to explain the geography of British imperial expansion and trade relations, as well as the organization and relations of labor, transport, and exchange in the zones thus incorporated into Britain's raw material periphery.

3. Albion notes, for instance, that the cost of animal traction limited the harvest of trees to an area of three miles or less distance from river's edge.

Similarly, for Innis, the incorporation of Canadian space into the world economy conformed to the material needs of British, French, and Spanish struggles for economic expansion and military power. The natural processes that transformed matter and energy in distinctive—topographically, hydrologically, geologically,and climatologically structured—spaces into fish, beaver, different kinds of trees, and different metals and fuels, together with the ways that river systems and land forms interacting with transport technologies created the cost of their export, molded Canada's social, economic, financial, political, and demographic organization.

For Innis, space as a differentiated condition of natural production—combined with space as an obstacle to exchange or export—determined the material composition and the location of different extractive economies. Naturally occurring spatial and material features set the parameters within which socially constructed technologies, markets, and geo-political forces determined the organization of labor, the settlement patterns and demographic characteristics of different populations, the composition of capital, the infrastructure capital was invested in, and the organization and structure of the Canadian state. The natural course, flow, and size of navigable rivers presented obstacles and opportunities to extract and export staples to world markets. Social organization and technological innovation created and adapted various means—vehicles and infrastructure—of transport. These mediated between space as a natural obstacle to access and exchange and rivers as an avenue of cheap access and export.

Space, and the topographic characteristics that determined the type and abundance of material production in that space, set the parameters for transport systems. These systems in turn determined the utility of the resources available and the cost of their extraction and export. They thus determined not only the structure, cost, and profitability of each separate extractive export economy, but also national social and political structure. State's and society's obligations to pay for these systems affected financial, economic, and political organization of the Canadian nation in enduring ways.

Like Albion, Innis related materio-spatial features of both the European core and the North American periphery to the patterns of settlement and exploitation of the newly incorporated areas. Britain lacked France's access to cheap salt, and so was obliged to settle and defend land-spaces to dry cod caught on the Grand Banks while her rival could salt the fish without landing. This disadvantage in fishing later gave Britain an advantage in moving across the Pre-Cambrian shield surrounding the St. Lawrence. The British first used this river for access to the Artic zones. There, cold temperatures and thin human populations created the best environments for the fine thick furs favored for elegant comfort in European winters. Trade routes, transport and ware-housing infrastructure, military posts, and settlements developed to support the high-value, luxury commerce of beaver pelts, particularly around the make-bulk and break-bulk affluences of tributary rivers into the larger stream. These later facilitated the influx of capital and labor for extraction of the timber required by the expanding military and commercial transport fleet in Britain.

The initial advantage that the British acquired in the control of the St. Lawrence river meant that the Hudson Bay Company paid relatively higher prices for beaver than the French could afford. When a French company penetrated Hudson Bay and established that route to Europe as a shorter distance accessible to larger ships than the St. Lawrence provided, the British were able to coopt the French agents into the Company's supply networks and thus control this more economical route to markets. The shorter trip and larger ships significantly reduced the cost of raw materials in England. The accumulating materio-spatial advantages contributed to Britain's eventual expulsion of the French from Canada. The shift to Hudson Bay favored the British economy, but led to significant economic stagnation of the established commercial centers along the St. Lawrence until the national state—under pressure from the wheat farmers initially brought in by the cheap fares, open lands, and seasonal wages made available by the lumber trade—supported the construction of canals and locks to improve, and rail lines to supplement, the river's natural channels.

Innis's comparative analysis of beaver, fish, timber, and wheat showed how the physical features of the natural resource, the topography of its natural location, and the character of its end uses and markets affected settlement and commercial patterns as well as social, economic, and political organization. These same factors determined the ratio of value to volume of the raw material exported, and thus the distribution of costs and profits along the localized nodes of its trade. The physical features of the raw material and of its sources in nature also determined the intensity and organization of labor, its demographic characteristics and location, and the costs and requirements of its reproduction. Combined, these factors determined the ratio of the volume of inbound provisions to outbound products. The beaver pelts sent down river and on to Europe, for example, occupied far less cargo space than the goods and provisions sent from Europe in trade. Logs and wheat both reversed this proportion of inbound to outbound cargo. This ratio of imports to exports determined the relative cost of freight or of passage on the inbound and outbound trip. Extra cargo space on a boat from Europe provisioning the beaver trade from Europe was very costly; passage on a timber boat returning relatively empty to Canada was far cheaper. These relative costs directly affected the cost and thus the rate of immigration, and thence settlement patterns and the cost and availability of labor. These in turn determined the cost of imported relative to locally produced goods, and thus the chances of establishing local productive economies.

The scale, type, and cost of transport technology responded to the material characteristics of the goods transported and to the size and topography of the rivers transited. City location reflected the logic of make-bulk and break-bulk locations determined by the volume of matter and the relative size and navigabililty of rivers and by the dendritic patterns formed as tributary rivers joined to form larger waterways.

Innis's theorization of matter and space did not preempt, but rather facilitated and extended, his analysis of social and economic processes. By integrating social and natural mechanisms, he could account for such temporally and spatially consequential phenomena as the changing demand and size of the world economy, the political and economic dimensions of empire and colonial resistance, or the role of conflicts in the core, first between Britain, France, and Spain, and later between the United States and Europe. Incorporation of materio-spatial data enriched his analysis of the economic, financial, and political trajectory of the Canadian nation and state.

Even the most precise of the more recent studies of the material and economic effects of space lack this close-grained analysis of specific commodities in particular places. Mandel's (1975) discussion of how technological innovations in transport reduced the natural tariff barriers of space shows considerable sensitivity to some of the physical attributes of space. Douglas North (1958), and later O'Rourke and Williams (1999), in their specific consideration of technical change in transport and its effect on world trade, attend to space as the naturally autonomous locus of socially produced technology and infrastructure. These works, however, do not achieve explanations of the interactions between space as condition of production—and therefore determinant of the kinds of economic activity apt for profitable exploitation—and space as obstacle to exchange—and therefore determinant of the location of materially bound human activity. They thus cannot achieve the dynamic dialectic that characterized Innis's or Albion's work, and that Wittfogel found in Marx's analysis of naturally produced use values. They do, however, provide paths that can contribute to analyses that integrate locally observable dynamics into world-systemic relationships.

Studies of extractive economies in the Amazon Basin provide similar paths. Their authors confront materio-spatial constraints on economy and society too obvious to ignore. Barbara Weinstein (1983), for instance, in her study of the rubber economy, notes that the Amazon Basin as an object of analysis is spatially so enormous and topographically and biologically so complex that it overwhelms the modern tendency to ignore or deny the effects of natural space on human social and economic observation. She does not explicitly analyze the effects of space and topography on the organization of the rubber trade, but the data she presents as the empirical bases for her explanation of the rise and fall of Amazonian prosperity allow a fairly detailed vision of these effects and a judgement of their importance.

Roberto Santos's (1968, 1980) earlier and more detailed analysis of the activities of local rubber-trading firms and of their financial, social, and commercial relations with each other, with their own labor forces, with the state, and with the international buyers and suppliers that located in Belém and Manaus provides an even richer source of empirical detail. Santos appreciates space as the biologically and hydologically determined locus and condition of natural production and of space as topographically and hydrologically determining the location and relations of social production and exchange.

In these and in other works on the Amazon, it is consistently clear that the river shaped human activities far earlier and in greater degree than human activities ever changed the river. Santos's and Weinstein's descriptions, together with ecological analyses of the Amazon and its tributaries by Nimuendaju, Palmatary, Lathrap, Sioli, and Fittkau, provide data and conceptual tools to construct a model of how space, topography, biology, and demography in the Amazon interacted with, responded to, and influenced industrial growth, technical innovation, international trade, and the geopolitics of the world-system.

In *Underdeveloping the Amazon* (Bunker, 1985), I elaborate such a model as a sequentially cumulative series of socially organized extractive cycles molded interactively by (1) technological, geo-political, and market transformations within the world-system and (2) the demographic, ecological, political, and economic conseqences of local social efforts to take advantage of the opportunities these changes in the world-system created. Local spatial and material configurations constrained both local and world-systemic actions in each cycle. My strategy was to extend the mechanisms of stages of autocatalytic diversification and growth that underlay models of ecological succession to include the sequentially accumulated ecological and social effects of each extractive cycle on both the social and natural resources available in subsequent cycles.[4] The following sections detail how local and international actors in these successive extractive cycles responded to and mediated between the changing technologies and markets of world capitalism on the one hand, and the local spatial and material features that formed the substance of their participation in the world economy.

4. The term "sequentially cumulative" emerges from my reading of Arrighi's (1994) demonstrations that each systemic cycle of accumulation incorporates and surpasses the expansion achieved in the earlier one it superceded. This idea is remarkable similar to classic formulations of ecological succession.

SPACE IN THE GEOPOLITICS OF COLONIZATION AND IN THE SUBORDINATION AND DECIMATION OF INDIGENOUS POPULATIONS

The Portuguese first settled and fortified the Amazon because it provided a hydrologically defined space available to Dutch fleets to penetrate the sugar plantations of the Northeast or to Portuguese fleets to protect that commercially profitable space. In order to cheapen administration and defense of the Amazon, the Portuguese crown ceded huge concessions of land and rights to indigenous labor to its officers.

The Amazonian space was not appropriate—biologically, hydrologically, or climatologically—to the technologies or to the labor relations preferred by the Portuguese. Portuguese economic exploitation of the Amazon was never profitable enough to purchase or to sustain imported labor. Instead, the Portuguese enslaved the indigenous population and exploited its captive labor to construct edifices and roads as well as for extraction of forest and river products. Costs of extraction rose and profits fell as these expeditions depleted the most proximate sources of labor and material.

The conditions of work and living in an increasingly impoverished settlement, combined with exposure to exotic germs brought in on ships from Europe, caused numerous epidemics and consequent reduction of native populations. The need to replenish their vulnerable supply of captive labor drove the Portuguese to mount more slaving raids and to provoke slaving wars. These raids and wars drove the remaining indigenous population further and further upriver. This increased the distance travelled on subsequent raids: this increased the need for provisions—for Indian rowers on both legs of the journey and for captured Indian slaves on the return. Both rowers and new captives suffered malnutrition, disease, and death from attempts to economize transport across this ever greater space (Hemming, 1978; Sweet, 1974).

The densest indigenous populations had located in the mouthbays of tributaries to the Amazon, where the calmer waters provided access to fish and turtle protein and the seasonal floods maintained soil fertility. The mouthbays and *varzeas*—spaces with abundant fertile grounds to cultivate and waters to fish—became spaces dangerously accessible to the Portuguese slavers' boats. Portuguese slaving drove the populations that survived war, disease, and enslavement to flee up the tributary rivers, to the less fertile land and the less rich waters of the terra firme. Enslavement, disease, war, flight, and refuge in less fertile environments hugely reduced indigenous populations.

The naturally occurring attributes of space, and of matter within it, had facilitated and enhanced certain human activities such as hunting, fishing, cultivating, and transporting, while constraining other activities, including European styles of agriculture. These same attributes of space structured Portuguese violence and exploitation and indigenous reaction and flight. The interaction between these natural and social forces created a demographic vacuum that seriously impeded local response when technological and industrial changes in Europe and in North America created rapidly growing demand for Amazonian rubber.

HOW SPACE, TIME, AND MATTER STRUCTURED RELATIONS OF PROPERTY, LABOR, AND EXCHANGE IN THE RUBBER ECONOMY

The ravenous demand for rubber started early in the second industrial revolution. European inventors, engineers, and capitalists had found ways that combined iron, coal, and steam to provide matter and energy for machines that performed an increasingly broad range of work. These machines could move far greater loads more rapidly and apply far greater force at much higher temperatures than either human or animal effort could manage. Innovation and capital rapidly extended these functions to the development of machines that transformed iron into other machines.

The firms that pioneered these innovations realized huge and expanding surplus profits; the national economies in which these firms participated realized rapid economic growth. Additionally, the states that directed these national economies greatly increased their revenues and their powers. Control over the raw materials that made up and powered these machines and over innovations that extended their productive use were of critical importance to these states and firms. Many such innovations stimulated discovery and use of new types of raw material; others adapted machines to the physical and chemical properties of the new types of matter discovered or processed.

The iron-coal-steam triad accelerated the historic interplay between technology and capital on the one hand and matter and space on the other. Some of the most rapid and dramatic episodes of this interplay occurred as engineers sought to adapt their machines to the very different chemical and physical properties of different deposits of iron and coal and as states and firms searched for new sources of material. These new sources had to be (1) large enough to sustain the expanding scale of new technologies and (2) of chemical and physical compositions that enhanced the performance of their machines and the quality of the commodities they produced.

Innovations and improvements in these machines and the extension of the kinds of jobs that could be mechanized increasingly required the transmission of motor energy between different planes. Metallurgical techniques were not yet exact enough, nor was machine-tooling precise and standardized enough, to achieve this transmission through mass-produced systems of steel cogs, wheels, and shafts. Flexible belts strong enough to hold their shape and texture through heat and friction were cheaper and more practical. Fabrics and rope tended to slip against restistance, and also wore out fairly quickly. Rubber provided greater strength and grip, but tended to stretch.

The growing importance of steam-driven pumps and motors to business profits and to state revenues from an increasingly mechanized world capitalism stimulated searches for technologies that stabilized rubber even under high temperatures and friction. Goodyear's invention of vulcanization first achieved these goals in 1939. Rubber thus treated served for the transmission of mechanical energy with flexible belts and for tires to allow mobility for these machines. Subsequent research and investments improved vulcanization. These improvements progressively extended the profitable mechanical applications of rubber. At the same time, technical innovations, particularly the invention of the bicycle and the automobile, and then the rapid mechanization of military force, added to the hugely expanding demand for rubber.

The rapid expansion of mechanical uses of steel and the rapid development of new mechanical technologies eventually generated incentives for the invention, fabrication, and standardization of machine-tooled screws, cogs, wheels, and shafts. Once these new inputs were possible, the steel of which they were made transmitted more force, resisted greater heat, and lasted longer than rubber. At the beginning of the machine age, however, rubber's material qualities—both natural and socially improved—allowed less technically demanding performance of these highly profitable functions.

Rubber of a quality found only in the Amazon worked best for these new technologies. Much of the most profitable research into and development of new technologies were thus based on Amazonian rubber. Incremental refinements in this technology combined with inventions of new mechanical applications drove demand for rubber far higher than local labor and transport systems could supply. Prices soared, and the local attempts to respond to this booming demand radically changed the economy, the demography, the politics, and the law in Amazonia. Materio-spatial features of the Amazon and the social and economic history of European responses to them made full response to the soaring demand impossible. Local attempts to corner or manipulate the market made the inadequate supply erratically volatile.

The rubber boom coincided with one of the most dynamic episodes of material intensification and spatial expansion of the world economy. The discovery of vulcanization and the rapid proliferation of new mechanical uses of rubber closely parallelled the development and diffusion of Bessemer conversion for smelting iron, which made durable steel of uniform quality cheap enough for mass production. The introduction of Bessemer steel is generally credited with the rapid ascent of the U.S. economy in the second half of the 19th century. The

U.S. led the world in its rate of adoption of Bessemer converters, and rapidly achieved primacy in both world production of steel and in world extension of railroads. The U.S. had surpassed the longer established steel industries of Britain and Germany by the 1890s, though European steel production was still expanding rapidly.

The new steel-based technologies that depended on rubber provided huge surplus profits and stimulated major economic growth in the rapidly industrializing core, particularly in Britain and in the United States. Industrial firms there, and national states, were intensely interested in the supply and price of rubber, but had to adapt to the materio-spatial, the economic, and the political structures of the Amazon to satisfy their needs.

The local actors who organized to take advantage of the new demand for rubber were directly constrained by (1) the biological characteristics of the rubber tree, *hevea brasiliensis*, particularly as those characteristics determined the spatial distribution of the tree itself and the temporal distribution of the labor process involved in tapping, collecting, and curing the rubber, (2) the course and flow of the rivers that provided the only commercially viable access to the *seringais*, or rubber groves, and (3) the seasonal patterns of rainfall and flooding.

The biology of the trees, and their distribution in space, had evolved to a very wide dispersion of single trees across spaces broad enough to impede the proliferation of *dothidella ulei*, a fungus that would thrive in the presence of thick groves of trees. The sap of this tree dripped slowly enough that only a cup could be collected every second day. Exploiting the rubber trees thus required single individuals to walk great distances between trees to collect a relatively small amount of rubber each day. They then had to cure the rubber and agglomerate it in small daily increments into a large ball for eventual delivery against their debts to the capitalist who had transported and provisioned them.

Just as the high cost and slow speed of animal traction limited the 17th century logging described by Albion (1926) to trees three miles or less from river's edge, the time and effort of carrying latex through the jungle limited the paths, or *veredas*, to distances within an area that a man could tap and carry to river's edge in a day's work. The inward transport of labor and provisions at the beginning of the dry season, and the outward transport of labor and rubber at the beginning of the rainy season, depended completely on the course and flow of rivers; so rivers determined which *seringais* could profitably be tapped. The low density of rubber trees and the restriction of tapping to trees within a day's round-trip circuit from a river meant that response to increasing demand required longer voyages up-river. This increased labor and transport needs and so drove up the costs and prices of rubber.

The absence of human population in this space, result of the earlier exploitation of slaves, imposed the need to transport labor and then to control and discipline that labor across space. The low density of trees, the slow dripping of latex from them, and time-consuming, daily, chore of curing and agglomerating the latex into solid bulks required that labor was widely distributed over long periods of time. Capital had to be advanced sufficient to sustain the workers transported long enough to accommodate the slow, biologically set rhythms of latex dripping and the slow, materially set, process of smoking, curing, and agglomerating it. Control or supervision of this widely dispersed, very slow, labor process would have been excessively costly. Direct control of labor, direct security over the capital advanced for its transport and provisioning, and physical security over its product were all impossible under these conditions.

Time, space, and matter all threatened the capitalist's ability to assure that he could appropriate rubber as return and profit on his investment. Capital was thus impelled to organize the labor process through devices that guaranteed returns on investments in transporting, sustaining, and disciplining isolated laborers at great distance over extended periods of time. One solution was to prevent boats owned by other merchants from providing transport of labor or product to rubber tappers, who might choose to sell the rubber they had tapped and flee to avoid the debt that capital claimed for their transport and provisions. Another was exemplary violence against any such tapper unlucky enough to be caught unprotected.

The rubber traders, or *seringalistas*, devised customs, and the state devised legal forms of property and usufruct, based on the flow of rivers, that designated the owner or lessee of a *seringal* as the sole legitimate claimant to rights of transport on each river. These rights could be enforced by violence. In this sense, the material and spatial natural configuration of rubber trees and rivers created the parameters within which social, economic, and political relations of property, extraction, transport, exchange, and law could be arranged to fit both the local ecological and social situation and the global economic demand.[5]

The same spatial and material configurations that constrained and molded the local organization of rubber extraction also limited and destabilized supplies to an industrializing world increasingly dependent on and enriched by rubber's

5. The whole system took the name of the Portuguese word for providing (*aviamento*). Merchant capitalists in this system were know as *aviadores*. The rubber grew in *seringais* leased in long-term *aforamentos* to *seringalistas*. The *seringueiros* delivered the rubber they tapped and cured to pay off the debt for transport and provisions. The

role in production. The potential for profit in rubber-dependent technologies accelerated even more when bicycles, and then automobiles, entered consumer markets as pioneer instances of machines made as consumer items for end use rather than as inputs for production.

The natural constraints on supply catalyzed both the scientific efforts to improve vulcanization sufficiently to expand the utility of lower grades of rubber and the efforts of the British state and colonial administration to transform the rubber cultivar from a feral resource to a domesticated cultigen. These efforts eventually transformed rubber from a wild plant where British capital "controlled neither land nor labor" to a plantation crop in Asia, where British capital controlled both (Brockway, 1979).

The flood of plantation rubber onto world markets in 1910 reduced the price of rubber below the costs imposed by the widely dispersed distribution of feral rubber trees in the Amazon and the high costs of the transport needed to extract and export it. The ports and boats of the *aviamento* system were too costly to maintain under this new price regime. Most were allowed to deteriorate while their diminishing use values were applied to a vastly reduced trade in rubber, gathered now by autonomous peasants as a supplement to diversified subsistence actitivities.

Space and matter thus defined the mode by which the Amazon was reincorporated into the world system as the source of a critical raw material. At the same time, space and matter created the conditions that eventually led coalitions of social actors in the core to search for technological and organization means to increase and stabilize the supply and to reduce the cost of rubber. Agents of industrial firms and of imperial states collaborated to move its material reproduction and to import colonial populations for its cultivation in these new locations. These initiatives ultimately impoverished the Amazon's economy as rapidly and radically as the local responses to growing core demand had enriched it.

Rubber was not the only input into the rapidly developing iron, coal, and steam-based technologies that so expanded the economies of scale in industrial production and the rates of growth and profit in industrializing nations. The Bessemer process depended on low sulphur ores and fuels and on manganese to combine strength with durability. The rapid expansion of steel processing required mechanization of mining and of loading for transport. New technolo-

seringalista or the *aviador*, who might or might not be the same person, set the prices for provisions and transport and for the rubber that was delivered against them. Tappers' debts thus tended to be perpetuated across seasons.

gies were developed for stripmining and loading, but at first they required large surface deposits of soft ore. These characteristics—soft, low-sulphur ore in large superficial deposits—were discovered in the iron-ore deposits of the Mesabi range in the Northern Great Lakes region. There, the complex interdependence of natural resource characteristics, topography, hydrology, technology, economies of scale, and massive accumulation of capital supported sustained development around the Lakes, even through the ore-supplying areas suffered relative economic collapse as resources depleted and technologies changed. The deposits on Mesabi, at that time the largest ever exploited, were sufficiently great and sufficiently concentrated to allow science, technology, and capital to discover and implement new economies of scale and speed. These materio-spatial properties of iron allowed owners of mines, ships, docks, and railroads to accommodate the rapid expansion of demand. By the 1950s, decades of intensive exploitation of the highest quality ores had reduced the Mesabi deposits to taconite. This ore is much harder and thus more costly to mine and process than the soft ores that had favored the early technologies of steam shovels, drag lines, and dump loaders. Huge increases in the tensile strength of steel, in the precision of metal and tool working, in the power of motors, and in the efficiency of mechanisms to convert heat energy into mechanical energy and into controlled chemical reactions, had provided capital access to new mine and transport technologies. The economies of scale—particularly in the hull size and strength of boats and in the power, weight, and fuel efficiencies of internal-combustion motors—that these new technologies supported made it possible to exploit Australian, South American, and African deposits. By 1973, iron ore and coal could travel the thousands of miles between these sources and Japan more cheaply than U.S. Steel could move ore from its mines on the north of the Great Lakes to its smelters on the south. Stronger rail systems and more efficient diesel motors made it economically viable to haul huge loads of iron and coal out of mines far more distant from navigable water than the Mesabi deposits are.

These new technologies, combined with the continued discovery of larger deposits of higher grade ores in places so far from industrial centers that earlier transport technologies left outside the sphere of competitive exploitation, obviated any impulse for capital to support technical searches for a material substitute or alternative means of procurement for iron, These same technologies and discoveries interacted with the ways that geology and chemistry had distributed iron and coal deposits across the globe to create a strong impulse to cheapen transport of bulky material across wider spaces. U.S. Steel suffered devaluation of the capital it had invested in infrastructure and technology appropriate to the chemical composition of the Mesabi ores and to the size of ship that could sail on, and between, the Great Lakes. The steel industry of Japan, Europe, and

Korea, however, exploited the cheapened transport of matter over greater distances, increasing both the material intensity and the spatial expanse of steel production.

In comparison, the dispersal of rubber trees and the slow biological rhythms of their internal circulation of latex so constrained tapper's and trader's ability to expand supply that consuming firms and states collaborated to alter the spatial, and thus the social and political, features of rubber production. States and firms were later impelled to change rubber's material features as well. U.S. and German efforts to circumvent the impediments of intercore wars on their access to Asian plantations accelerated their search for techniques to fabricate rubber synthetically from petroleum. Their success expanded the supply and reduced the price of raw material essential to the huge cheapening and expansion of automobile, truck, and airplane traffic after World War II. It also further depressed the price of natural rubber.

TOPOGRAPHY AND HYDROLOGY IN THE EXTRACTION OF PLANTS AND ANIMALS

Multiple studies of floral and faunal extraction in the Amazon provide complementary perspectives on the ways that matter and space first mold local responses to world-system demand for new resources and then structrure the ecological and social conseqences of these local responses. Data presented by Alden (1976) and by Sweet (1974) on the extraction of rosewood and cacao; by Nigel Smith (1974, 1980–81) on the extraction of turtles, manatees, and caymans, and the consequent impoverishment of biological energy capture and exchange in river and varzea; and in Fittkau's (1973) analysis of the spatial and material functions of the cayman in maintaining the fertility required for fish in the mouthbays of the tributary rivers all indicate the autonomy of natural spatial and material systems in the Amazon and the extent to which successful human extraction from these systems must adapt to them. The human activities may have profound, complex, and unpredicted consequences upon these systems, but these consequences themselves occur through the dynamic natural interactions of spatial and material processes, however much human intervention may have catalyzed these changes.

IMPLICATIONS OF AMAZONIAN EXPORT CYCLES FOR MATERIO-SPATIAL ANALYSIS

Human endeavors to exploit the resources produced in specific locations can only succeed if they adapt to the material and spatial features of those locations. In all of the Amazon's extractive cycles—the slave wars, the trade in turtles, fish, cayman, manatee, and capybara, the rubber boom and its eventual decline—the river system as a hydrologically, topographically, materially and biologically differentiated space created the conditions for the reproduction of the resource extracted and the means of its transport. The hydrology and the topography of the river directly shaped the human activities aimed at profitable extraction. In the case of rubber, they directly limited the speed and proliferation of core technological innovations that incorporated rubber into an expanding range of increasingly productive and profit-generating machines. The materio-spatial attributes of rubber and of the river system that conditioned its natural production and commercial access to it affected the economic opportunities and the social and political organization of firms and states in the industrializing nations as much as of local merchants, rubber-tappers, boat owners, and politicians. The ways they affected these different social groups, however, and each group's behavior in response, varied enormously according to their different positions in relation to these materio-spatial characteristics and to the technical and economic processes these characteristics gave rise to. The consequences of these actions—their costs and their benefits—were unevenly distributed in the same way. In this sense, the dynamic, sequentially cumulative processes of technological and social organization innovations in extraction, transport, and processing of matter emerge from reciprocal and interactive dynamics between local and global instances of nature and society.

These reciprocal dynamics belie notions of the social construction of nature and of space. Humans do not transform or construct space socially; at most they accelerate and intensify their own transit and their transport of matter across it. Time does not annihilate space in this model, rather space as condition of production provides opportunities, and space as obstacle to and cost of transport constitutes the challenges, that foment innovations in social organization and technology.

My attempts to model these dynamics originated in the Amazon, where they are eminently salient and therefore visible. In the following sections, I will endeavor to explain how I have attempted to carry this model forward into an explanation of how space and matter—as the contradiction between the cost of distance and economies of scale—have driven the progressive globalization of capitalism. I will show how the tension between economies of scale and the cost of space creates technical and organizational challenges that foment social, political, and economic, and technological innovations. Implementation and extension of these innovations have expanded the productive and commercial space and the transformation of matter in each systemic cycles of accumulation (cf. Arrighi 1994).

The long-term, sequential cumulation of these transformations constitute the underlying mechanisms of globalization. I will maintain a focus on the global

consequences of local processes in the Amazon to demonstrate that even as the outcomes of these processes become global, their origins are rooted in locally observable and specifiable materio-spatial features. These features present the challenges and the opportunities that generate the economies of scale in transport and in technology that have driven the centuries-old progress of globalization.

The core explanatory mechanism in this model relates the succession of materio-spatial configurations in Amazonian extractive economies to the timing and material needs of technological innovations. The timing, as well as the sequentially cumulative scale, productivity, and profitability, of these innovations both drive and reflect the material intensification and the spatial expansion of the world capitalist economy.

This sequence of new technologies intersects and interacts with material resource discoveries in particular spaces. These discoveries often motivate or accelerate the incorporation of previously external peripheries into the world-system. Local actors—sometimes indigenous or previously resident, but often immigrants responding to the economic opportunities the recently discovered resource provides—drive political, social, economic, and financial reorganization in their endeavors to profit from these new demands. Their profits depend on adapting to and exploiting the materio-spatial features of the resources in ways that satisfy the technical needs of the processes of production and the financial needs of the states and firms that control these techniques.

Local elite responses to the pressures and the opportunities that the expansive and technically driven world-systemic demand for raw materials creates change the ecology that they are exploiting, generally reducing its capacity to keep up with that expanding demand. When the lag between global demand and local supply becomes too great, firms and states of the industrial nations choose among and combine several different strategies. These include: (1) searches for new sources, generally larger and with physical and spatial characteristics more compatible with new industrial demands, (2) technical innovations that cheapen access to these new, larger sources, and (3) invention, improvement, and cheapening of synthetic substitutes. Each of these alternatives materially intensifies and spatially expands the world economy while devaluing the capital the local economy has sunk into adapting itself and its environment to world-system needs for its resources.

I used the empirical narratives of the boom and bust of each of these extractive episodes to model the materio-spatial consequences of depletion and of diseconomies of scale in most extraction. From these narratives, I deduced that states and firms in the core mobilized science, commerce, and imperialist or colonial forces to resolve problems of rising cost, scarcity, or inconsistent supply to (1) find another or other sources of the raw material in question in other locations and to organize or catalyze the transport systems that would ensure a cheap and steady supply of these materials across the spaces thus incorporated into the world-system, (2) find natural or devise technical or synthetic substitutes for the raw material in question, as happened with the technologies that substituted petroleum for many of the uses of oils provided by, inter alia, manatees and turtles, and for many of the uses of rubber, or (3) domesticate and convert to plantation cultivation the natural or feral sources of the raw material, and import or organize a population sufficiently controllable to provide a cheap and stable labor force, as happened with cacao and with rubber.

All three of these solutions manipulate material process, both natural and social. They relocate sources according to social (i.e. demographic, political, and geopolitical) and natural (i.e. climatological, podological, and geological) attributes as these relate to the material requirements of the reproduction and extraction of the raw material and to the spatial, topographic, and hydrological determinants of the cost of access and transport. All three of these solutions provide mechanisms to explain the secular spatial expansion and material intensification of world-systemic production and exchange.

I used this spatio-material model to organize my analysis of the local consequences, environmental and social, of each extractive economy and of the changing demands for raw materials in the world-system, but I abstracted these processes upward into a thermodynamic model of unbalanced energy flows to account for the systematic underdevelopment and instability of extractive economies.

After finishing *Underdeveloping the Amazon*, I started to work on the implications of this model for Marx's theory of rent. I found David Harvey's (1983) otherwise very helpful discussions of rent and of the built environment too compromised by his focus on finance and on urban phenomena to apply directly to material analysis. At Johns Hopkins, two of David Harvey's students, Kevin Archer and Michael Johns, took a seminar in which I was trying to work on these problems. Michael and Kevin challenged and pushed me toward a more nuanced interpretation of Marx's views of use values and their transformation into exchange values.

During that same period, Martin Katzmann's (1987) extended critical review article of *Underdeveloping the Amazon* appeared. This was essentially an encyclopedic summary and critical deployment of neo-classical resource economists' claims that vent-for-surplus of natural resources was a regular and reliable means for the economic development of "newly settled" frontiers. Simultaneously, Robert Volk (1986) claimed in a review that Marx's labor theory of value provided all the mechanisms required to explain why "enclave economies" led to unequal development.

These challenges from the left and from the right, and the directed reading of literature I had previously ignored that Katzmann's bibliography led me to do, drove me to search for the reasons that some extractive peripheries, most notably the United States, but also Sweden, Denmark, parts of Germany, Canada, and Australia, had subsequently industrialized sufficiently to achieve at least partial participation in the core. I gradually became convinced that notions of unbalanced energy flows were too abstract and too aggregated to permit analysis of the specific binary and multilateral production and exchange relations that structured and periodically reorganized the world economy. The physical and chemical attributes of raw materials, and their location in space as mediated by topography, hydrology, geology, climate, and biology provided much more direct bases for explaining the social and geopolitical strategies for the extraction, transport, transformation, exchange, and consumption of the secularly expanding diversity and volume of commodities.

The deployment of these strategies necessarily intersected with the economics and geopolitics of space. This intersection implied that materio-spatial mechanisms aided not only in the explanation of specific economic strategies, but also underlay the ways that these strategies molded social structure, agency, and organization from local to global levels.

Wittfogel's compilations of Marx's analsis of natural systems in the production of use values, my own readings of Marx's theory of rent (Bunker, 1986, 1992), and Carolyn Merchant's (1983) discussion of Francis Bacon's and Agricola's views on the imperative that all human uses of natural systems succeed only as their technology responds to material and chemical attributes of these systems, all point to the ways that the physical and chemical attributes of different kinds of matter enter into all human technological improvements. The very diversity of matter dispersed across space provides the material and spatial means of the secular intensification, proliferation, technification, and expansion of both types and volume of material production that drive the system's dynamic of growth and change. These considerations convinced me that Wallerstein's tripartite categorization of the world system, and his tendency to use a categorical logic instead of materially and spatially grounded mechanisms to explain the dynamics of growth and change, impeded an adequate specification of particular or local economies.

Harvey (1983) elaborates his own concepts of the built environment combined with a synthesis of van Thunen's central place theory into an appreciation of Marx's theory of rent. In this effort, he explicates Marx's insights into capital's dependence on the state to redistribute the huge sunk costs of transport technologies and infrastructure to include the various economic and social agents that benefit from them. Marx was very clear that these sunk costs had hugely expanded as coal, iron, and steam made new transport means possible and then provided use values that could only be realized as these new transport technologies moved them cheaply in bulk from their dispersed locations to the increasingly agglomerated urban-industrial centers that machino-facture brought about. Because Harvey is so focused on the internal dialectic of capital, however, he does not fully appreciate the extent to which Marx's rent theory specified the social and political implications of his abstract affirmation that nature and labor are inextricably interdependent in the production of commodities.

Harvey's insights into rent, transport, and the built environment complement Innis's (1933, 1956) conceptually different but analytically complementary explanations of the costs, dynamics, and political/organizational consequences of transport systems devised to satisfy core demands for peripherally extracted raw materials. Reading Harvey and Innis together helped me to extend and refine my notions of transport systems as a capital-intensive, debt-creating, state-forming instruments to articulate dispersed site-specific raw material sources with concentrated centers of industrial production, capital accumulation, and political power. Materio-spatial analysis of the financing, construction, and use of specific transport systems' technology and infrastructure in specifiable times and places reveals the specific interests and activities of different groups in both core and periphery. Such analysis can explain how transport technology and infrastructure progressively cheapened and accelerated the consumption of natural resources in each cycle of world-systemic material intensification and spatial expansion.

Materio-spatial analysis of (1) specific extractive economies and political formations of peripheral zones, (2) the technologies, composition of capital, organization of labor, and state formation and reformation in core economies, and (3) transport and communication systems that facilitate and cheapen the flow of material and information between them reveal how these processes have driven progressive globalization. These attributes, and the secular evolution of the technological and political systems they generate, mold the strategies, costs, spatial extent, and profits of core initiatives to exploit multiple diverse peripheries for their varied natural resources. The transtemporal continuity of interactions between social, spatial, and material systems explains the sequentially cumulative processes that have expanded and intensified productive and commercial relations through each systemic cycle of accumulation.

This continuity belies any claims that globalization is a novel or recent phenomenon(cf. Sklair, 2000). Rather, it is the latest and perhaps ultimate stage in spatio-material processes that have evolved and accumulated sequentially through the specificable diverse activities and interactions of specifiable and locatable groups and organizations (Bunker, 1996; Bunker and Ciccantell, 1995 a, 1995 b, 1998, 2000, 2001; Ciccantell and Bunker, 1997, 1999). Paradoxically, it is only called globalization as these processes reach their global limits.

The sequence of Amazonian extractive cycles parallelled the trajectory and and reflected the technologies of production and transport in each systemic cycle of accumulation that occurred during the four centuries of Brazil's incorporation into the world system. The initial settlement and slave wars responded to Dutch-Portuguese struggles for trade dominance, both in sugar and in iron manufacture used for trade with indigenous groups (Sweet, 1974, Bunker, 1982). Destructive exploitation of turtles responded to luxury demand for combustible oils and for self-preserving meat for long, wind-driven ocean voyages before industrial technologies could convert petroleum into light, refrigeration, and motor power. The rubber economy's rise and fall coincided with and contributed to the apex of Britain's industrial and commercial dominance and with the rise of the American challenge in heavy industry. With the collapse of the rubber market and the dominant technologies' increasing use of mineral rather than vegetable matter as primary inputs, the Amazon remained little linked to world markets from 1920 to 1950, when the geo-politics of the cold war and the crucial role of steel in the post-war reconstruction of the European economy generated U.S. political and commercial interest in sources of manganese outside of the Soviet Union. Politically and economically powerful Brazilian groups responded to Bethlehem Steel's blandishments, forming a large company with substantial Brazilian government guarantees of U.S. Ex-Im Bank loans to export manganese from Amapá, the isolated and sparsely populated territory on the northern shore of the Amazon delta.

Manganese is an essential component of both Bessemer and open-hearth steel making. It is used in relatively small proportions to coal and iron—14 pounds per ton of steel—and is priced high enough that transport from the most remote parts of the globe was commercially viable. The Serra do Navio deposits were highly concentrated in an area 20 miles from a deep water port. Construction and then operation of mine, railroad, and port generated considerable prosperity within this coastal enclave and huge profits for the concentrated capital that controlled it, but these effects were spatially and materially more limited than the effects of the rubber boom had been.

The parallel trajectories of (1) technologically-driven, scale-augmenting, sequentially cumulative cycles of material intensification and spatial expansion in the world economy and (2) demand-driven extractive economies of the Amazon crystallized in 1985, when, 20 years of complex political and economic negotiation and struggle after its initial discovery, Carajás, the largest iron mine in the world, commenced operation. The Companhia do Vale do Rio Doce (CVRD), a public/private Brazilian firm that already exported more iron ore than any other company in the world, owned, constructed, and operated the mine.

Construction absorbed the largest international loan for a mining project in history. Much of this capital was invested in the longest rail line and the highest capacity port in the world dedicated to a single mine. The determining criteria for the size of mine, port, and rail appear to have been the economies of scale required to compete in Japanese and European markets. These economies of scale had to be huge to overcome the diseconomies of space in constructing and operating a mine located 900 kilometers through dense rain forest and across multiple rivers from the nearest deep water port and producing such a high-volume, low-value commodity as iron ore. Even after the long and difficult haul through jungle, the port was still further from Japan than coal or iron had ever been commercially transported before. The design, finance, construction, and operation of the Carajás mine represented the latest step in the globalization of iron and coal markets by technical advances in the scale of mining, transport, and processing. Together with oil, these two materials are among the most voluminously consumed in industrial production. Competitive industrial performance therefore requires that they be relatively cheap. Even before iron and coal became globally sourced and traded raw materials, transport usually constituted over half of their landed cost. The technological innovations and economies of scale in mining, in transport, and in production that made Carajás iron ore competitive in Japan were also a major ingredient in globalization.

Far more than the international conspiracies of firms and states to assure a cheap and steady supply of rubber, this globalization of iron markets emerged from complex processes of collaboration and competition between firms and states in the core as they catalyzed and interacted with local actions and initiatives to adapt to and exploit the materio-spatial characteristics of the new extractive periphery. Contradictions between the ISI principles and ideologies of peripheral nations and the FDI strategies of U.S. based multinational firms had led in the 1960's to broad resource nationalism and to nationalization of many mines and processors. These trends deterred major mining companies from investing in exploration or in new projects. The World Bank, responding to core-wide concerns about potential raw material shortages, mobilized its own technical, financial, and diplomatic resources to coordinate and supplement loans from the U.S., Japan, Germany, the European Union, and Korea to bring the Carajás mine into operation.[6] The majority of this loan was to pay for the huge infrastructural

6. The timing of World Bank intervention and participation in the loan negotiations in 1982 and the Bank's willingness to relax its procedures to link disbursement of the

costs of transport, 890 kilometers of rail through the jungle and a deep water port capable of handling and loading 400,000 dwt boats at the coast.

The unprecedented size of this loan was proportional to the unprecedented scale of the mine and of the processing and transport infrastructure it required to export its iron. The scale of this infrastructure was designed around (1) spatio-material attributes of the iron ore deposit, (2) material and ecomomic attributes of the iron itself, (3) spatio-material and economic characteristics of the potential demand for and the eventual price of iron, (4) the economies of scale in transport that had brought about and were made possible by the latest stage in the material expansion and spatial extension to a global and ocean-based, rather than regional and land-based, market for coal and iron (Bunker and Ciccantell, 2001).

Within the Amazon itself, the proposal to construct this infrastructure had generated an intense polemic. The Tocantins river flowed 150 kilometers to the East of the Carajás deposits, through groves of Brazil nut trees (*Bertolensis excelsior*) whose products were shipped down the river for export from the port of Belém, the capital of the State of Pará. Original plans for exporting the iron through a partnership of US Steel and CVRD had specified a rail line from the mine to the river, barge transport to Belém, and reloading onto ocean going ships at Belém. U.S. Steel strongly opposed CVRD's preference for the much more costly project whose funding the World Bank eventually coordinated. Instead of going out through the river port of Belém, the iron would be exported from an ocean port in Maranhão, thus depriving the state of Pará of both the direct taxes and the indirect income that export from Belém would have provided.

Interview and archival research in Rio de Janeiro, Tokyo, and Washington D.C. on the origins of this controversy strongly suggested that CVRD and the national state had been induced by Japanese and, to a lesser extent, European, interests to support the coastal rather than the river option for export. Belem's port, at most, could accomodate 40–60,000 dwt boats; Maranhão could potentially handle over 400,000 dwt. Exports to US Steel in the United States would not travel long enough distances for the economy of scale in boat size to offset the additional fixed and demurrage costs of the larger ports.[7] European and Japanese

loan to completion of sequentially specified stages suggest that Bank efforts in this case may also have aimed at making Brazilian default on loans less likely.

7. The materio-spatial regularity in this case is that the water resistance again the hull increases as the square of the depth of the hull, while the volume of cargo increases as the cube of the depth of the hull. Fuel requirements per unit of cargo thus reduce with increased size of ship. At the same time, labor requirements increase proportionally less than ship size. These two constants create consistent economies of scale in shipping.

ports were sufficiently distant to do so, however. CVRD bought out US Steel's share in the partnership in 1977, for a payment of 50 million dollars.

CVRD, with World Bank support, thus played into and exploited Japan's strategies to dominate world steel and shipping markets. Japan's moves to dominate these trades eclipsed the formerly dominant U.S. steel and transport sectors. The technologies of mining, transporting, and smelting that had responded to and been fueled by the topography and geology of the Great Lakes region a century earlier were now constrained by these materio-spatial features to compete with the huge boats that deep water ports could handle and the enormous machines that the Carajás deposits could support.

CVRD's actions in these controversial undertakings demonstrate simultaneously, (1) the spatio-material processes and considerations that structure inter-core competition and collaboration and their effects on materially and spatially differentiated peripheries, (2) the consequential role of preferences and decisions of peripheral actors in the restructuring of peripheral-core relations,[8] and (3) the impacts of increasing economies of scale in the extraction, transport, and processing of the most voluminously consumed raw materials on the episodic, but cumulative (cf. Arrighi, 1994) spatial expansion and material intensification of the world-system through succession of distinct systemic cycles of accumulation.[9]

The materio-spatial processes and relations that thus structured political, economic, and financial relations around the social construction of plant and

These economies of scale are offset, however, by the much higher sunk capital costs of the infrastructure required for docking and loading cargo and for the greater costs of in-port delays incurred by a larger, more costly ship. The economies of scale are thus only realized where the voyage itself is long enough to offset the extra fixed costs of in-port handling.

8. Note the CVRD's preferences affected not only Brazil's position in the world system, but the entire world market for iron and steel. The addition of Carajás increased world supplies to a highly inelastic market, with implications for all exporters of iron and for all industrial processors of steel.

9. Japanese pariticipation in this multilaterally shared loan was itself a new step in the strategies to reduce capital exposure and risk through joint ventures and long term contracts that the Japanese had perfected in their dealings with Australia. In this case, the Japanese succeeded in extending the oversupply from excess capacity in world mines at proportionally small proportions by responding to and participating in the core-wide preoccupation with resource scarcity (Bosson and Varon, 1982; Bunker and Ciccantell, 2001)

transport infrastructure coincided with massive scale expansions in different core nations' steel industries. These included: (1) the peak of Japan's expanded production of steel and of ships to dominate world trade in both sectors, (2) Korea's entry into the world steel market through the construction of the largest integrated steel plant in the world, (3) European steel companies moving their processing plants to coastal locations apt for the larger scale of smelting and transporting that they needed to compete with the drastic cost and price reductions of steel achieved by the Japanese and the Koreans (Jornmark, 1993), and (4) the Plaza accords.

The scale expansion and relocation to coastal sites of the Japanese, European, and Korean steel industries and boat construction directly drove the spatial expansion and material intensification of raw materials markets, while the Plaza Accords enormously raised the exchange rates of the Japanese yen, increased the interest and capital costs of all loans made in yen, and lowered the real value of international sales of iron, which were transacted in dollars. The excess accumulation of liquid capital in Japan that led to the Plaza Accords (Murphy, 1996) was itself initiated by Japanese success in reorganizing the spatio-material distribution and the social organization of world metals markets in ways that fostered Japanese dominance of world steel and merchant marine markets. The cumulative result of these interdependent financial, spatial, and material transformations was the enhanced subordination of raw materials exporting peripheries to raw material importing nations of the core (Bunker and Ciccantell, 2001).

This subordination, however, involved the decisions and active participation by local agents in the creation of the capital-intensive infrastructure and adoptions of new technologies with massive economies of scale in mining and transport that supported the core advances in the scale of smelting and refining. CVRD decided to respond to the opportunities these new technologies opened in the Japanese market and to the facilitated access to huge credits opened by the coincidence of the world debt crisis and core country worries about future raw materials shortages by contracting huge loans to (1) increase the extractive capacity of the mine, (2) build the high-capacity rail line to the coast, (3) develop a port adequate to take boats so big that only Japanese ports and the port of Rotterdam could unload them and (4) engage in joint ventures with Japanese firms in ore carriers of over 450,000 dwt.

SPATIAL CONSEQUENCES OF LOCAL DECISIONS TO EXPLOIT GLOBAL MARKETS

At the site of the mine itself, and along the line of rail, the materio-spatial, topographic and hydrological features of the deposits intersected with the temporally conditioned cost of the capital required for the scale of plant and transport infrastructure chosen by CVRD. This intersection of natural and social forces constrained CVRD to coordinate the construction of all phases of the operation so as to come on line as simultaneously as possible. No component of the system could function until all were in place, so temporal disjunction in their completion would increase interest costs on what was in any event an enormously costly sinking of capital. The combined pressures of material, temporal, spatial, and financial dynamics led to a highly lumpy, concentrated use of labor in a relatively restricted space. This prompted both formally managed and spontaneous migration of labor to Marabá, the *municipio* where Carajás was located.

Marabá was then the major source of Brazil nuts and the center of a local trade organized to export them. *Bertolenis excelsior*, unlike *hevea brasiliensis*, grows in dense groves and yields its fruit in the rainy season, when water filling the drip-cups impedes the collection of latex. In other respects, though, the spatio-material features of the *castanheira*, or Brazil nut tree, favored the adoption of the basic material, financial, and social relations of the *aviamento* system. As in rubber, the trade was organized into large *aforamentos*, or long term leases from the state, held in such a way as to allow potentially violent control over access to and transport out of the groves. This system of property and labor relations evolved to permit the *aviador* to appropriate the harvest in order to secure the return and profit on the capital advanced to transport and sustain labor during the months of the harvest.

Migrants who failed to find employment in mine and rail construction, and later employees who were dismissed when all of the huge construction projects finished at the same time, could instead occupy and exploit the lands in and around the Brazil nut groves. The trees themselves depend biologically on the clustering of other trees both for protection against wind and to support a bee essential to their polination. Thus any agricultural use of land in or near a grove can drastically reduce the production of Brazil nuts. The *castanhaleiros*, or owners of the long-term leases, publicly announded that they would respond violently to any challenge to their control of property and of labor.

The state had established a fiscal incentive program to attract businesses that would share some of the infrastructural costs of the transport system. Violent conflict over land and resources threatened to disrupt the smooth implantation of the mine and of the other enterprises that CVRD and the national state were hoping to promote around it. The state responded to this threat by establishing GETAT, a land-policing quasi-military organization with extraordinary powers and authority. GETAT preempted the local state's ownership of the Brazil nut groves and thus its political capacity and authority in Marabá.

As in the rubber economy, the materio-spatial characteristics of the Brazil nut economy directly influenced political and legal institutions and processes.

The initiation of the iron mining economy, however, brought political, economic, and legal processes that were fundamentally at odds with those of the Brazil nut economy into the same space. The Brazilian national state, under intense pressure from CVRD and from Japanese financial and planning agencies, intervened to reduce the autonomy of the local state and of the municipio of Marabá, as well as to restrict the political power of the old Brazil nut oligarchy.

Local response to Japanese raw materials access strategies brought another, quite different, material process into this space. CVRD accepted an invitation to form a joint venture in an alumina refinery and aluminum smelter downriver from Marabá. The Brazilian government, and the public electric company, Eletronorte, were induced to build a huge hydroelectric dam across the Tocantins River to supply the aluminum smelters with cheap electricity. The Japanese government offered at first to participate in the financing of this dam, but after the Brazilian government was publically and fiscally committed to the project, the Japanese withdrew their offer, alleging that the project they had themselves proposed was not economically viable. Eletronorte assumed huge debt to finish the project, and guaranteed long-term prices for the electricity transmitted that turned out to be well below the cost of production and interest charges.

Rising energy costs in Japan had induced the Japanese state and Japanese firms to collaborate in moving the energy intensive aluminum industry out of Japan through joint ventures with national states that controlled large sources of bauxite. Because bauxite forms through the percolation downward of aluminum and the dissipation of the water-solvent silica that bonds to it, the richest deposits occur in flat areas in the humid tropics. Hydroelectric dams in narrow steep valleys provide the cheapest sources of the huge amounts of electricity required to separate the high valence oxygen in aluminum (AlO_3). Locating an aluminum smelter near a bauxite mine therefore makes little economic sense. The hydroelectric generation of the energy required to smelt aluminum near the best sources of bauxite require huge amounts of water spread over huge areas to compensate for the low height of dams in these relatively flat areas.[10]

Agencies of the Japanese state and of the Japanese aluminum industry, however, manipulated Brazilian aspirations for industrialization of the Amazon to gain local political and financial commitment to building these dams. They contracted a reputable and well-staffed development consultancy in Tokyo to carry out and publish an analysis of the economic and social benefits of electric genera-

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10. The amount of energy generated is a direct function of the volume of water times the height of the dam (Kw=VH).

tion in the region. These same studies also described ways that the dams would facilitate commercial transport on the "hydrovia" that they would make possible. They propogated the idea that the hydroelectric dam constructed for a regionally vertical integration of all three phases of aluminum production—mining, refining, and smelting—would promote additional industry through induced linkages to both aluminum ingots and the electricity. The Japanese contrived to reduce the cost to themselves of building an economically inefficient dam by inducing Brazil to assume most of the equity costs of these undertakings (Bunker, 1994 a, b). Electronorte was able to provide the transmission lines to the smelter, but could not then afford to extend lines to established communities. No locks were built around the dams, so they impede the local transport they originally promised to enhance.

At the time, the aluminum industry was controlled by six huge firms who used their oligopolic power to keep prices up by keeping supply well below demand. The history of these high prices influenced Brazil's state to accept the high capital costs of building the dam. CVRD agents were apparently not fully aware that the Japanese state and the Japanese aluminum industry were engaged in similar joint ventures with six other nations at the same time. These multiple joint ventures in smelting all came on line at about the same time and vastly oversupplied the market, leading to the price crash of 1982 (Bunker, 1994).

The Japanese strategy essentially involved an inversion of the materio-spatial logic of the aluminum oligopoly, which had located smelting, the most expensive and capital intensive phase of processing, in the industrialized countries. The Japanese strategy was to promote joint ventures with national states where bauxite was abundant and who might be induced to generate and sell electricity cheaply.

By manipulating the resource nationalism and desire for industrial development of bauxite-rich nations, the Japanese relocated the capital intensive—and energy intensive—phases of the industry to the periphery at the cost of the peripheral nations. The Japanese promulgated an over-simplified, wildly optimistic version of the vent-for-surplus notions that capital from raw materials exports could be invested in processing and transformation in such a way as to "capture" the linkage or spread effects of these materials. The Japanese incorporated these ideas into elaborately prepared and widely distributed technical studies of and projects for ways to maximize economic development through investments in natural resource extraction and processing, transport infrastructure, and hydroelectric generation. Japanese firms and agencies of the Japanese government combined these studies[11] with offers of participation in infrastructure and joint ventures in plants to induce the states of aluminum rich nations

to invest in dams and smelters (Bunker, 1989, 1994; Bunker and O'Hearn, 1992). National, state, and provincial governments in Indonesia, Venezuela, Australia, Canada, and Brazil were all seduced by Japanese offers to exploit their hydroelectric potential to smelt aluminum.

Japanese initiatives had catalyzed the globalization of iron and coal extraction and export by stimulating states and firms in distant source nations to invest in mines and transport in order to supply cheap raw materials to increasingly centralized, scale-economic smelters in the core. In aluminum, the tactics were inverted but the consequences were the same. Japanese initiatives globalized production by decentralizing what had been a highly concentrated, monopolistic system of smelting to the sites of raw materials supplies. Both strategies expanded the commercial arenas of these metals—creating excess capacity and cheap transport—at the cost of the supplying nations.

The Japanese found willing collaborators in promoting these ideas, particularly in CVRD and in those ministries of the national state that were primarily concerned with finance and foreign trade. Multiple decisions at the local level were the necessary conditions for the spatial expansion, material intensification, and organizational and financial transformation that globalized the world's aluminum industry. As does the case of Carajás and the decisions about the scale of its infrastructure, the bauxite-aluminum project rewards integrated analysis of local and global instances of materio-spatial process. Again, the local process is not simply an instance of a reflex of a global phenomenon, but directly drives the transformation of the global system.

In the course of these conceptually interdependent projects of research and analysis, I discovered that I could not understand the materio-spatial dynamics of extracting and processing iron and aluminum in Brazil without first understanding how the Japanese firms, sectoral associations, financial institutions, and state agencies had transformed and globalized raw materials markets (Bunker, 1992, 1994; Bunker and O'Hearn, 1992; Bunker and Ciccantell, 1994, 1995a, 1995b, 2000, 2001; Ciccantell and Bunker, 199, 1999, 2002). As I investigated Japanese raw materials access strategies, however, it also became clear that to succeed they had to remain highly responsive to local phenomena—political,

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11. The study proposing the construction of a hydroelectric dam to serve the aluminum smelter in the Amazon ran to seven volumes, printed on glossy paper with ample tables, graphs, and photos.

cultural, physical, chemical, and topographic.[12] These strategies had to adapt simultaneously to (a) the physical, chemical, and spatial features of the material itself; (b) the patterns of world supply, demand, price and spatial organization in the world market; (c) the political organization, political culture, and economic-policy ideologies of the exporting nations; (d) the market as structured by earlier dominant economies; and (e) the responses of the exporting nations to the specific measures the Japanese took to restructure the market to their own advantage (Bunker, 1994).

CONCLUSION: TRANSTEMPORAL COMPARISONS OF SPATIO-MATERIAL PROCESS IN MOVING FROM LOCAL TO GLOBAL

Each of the cases I have summarized here shows how local materio-spatial relations and processes in the Amazon intersect with, and partially constitute, the world system as it transforms, and is transformed by systemic changes in cycles of accumulation. Attention to materio-spatial attributes is necessarily ideographic and complex, but the discrete natural—physical, chemical, geological, hydrological, climatological, etc.—features of specific sites and the discreet social relations—technical, economic, financial, etc.—that respond and adapt in order to exploit them each manifest regular underlying processes and mechanisms. These regularities and mechanisms have different explanatory status; their potential generality varies accordingly. These variations are not an impediment to comparative historical analysis; rather, their different explanatory statuses allow analysis of the relative weight of the various natural and social factors as their interaction brings about site-specific and global economic and ecological change.

Identification of these regularities and mechanisms can thus support comparative analysis across material types and across time. Materio-spatial analysis provides a means to compare conjunctures across the cumulatively sequential changes in technology, production, and institutional density—both of state-firm relations in specific social formations and of the world system itself.[13]

12. Japanese negotiating strategies varied in Australia and in Brazil in ways that simultaneously took into account the very different relations of central and local state power in the two countries and the differences in distance between iron mines and the ocean(Bunker and Ciccantell, 2001).

13. Comparison based on site-specific intersections of materio-spatial regularities allows transtemporal comparisons that supercede Millian strictures that require control of all but one variable. Such comparison allows configurational (Tilly, 1995) and conjunctural (Paige, 2000) analysis in ways that overcome Paige's objections to the social scientific search for regularity and generality of explanation.

Incorporating the specific materio-spatial attributes that determine how diverse specific raw materials and the sites from which they are extracted participate in and affect the world-system requires a range and scope of empirical and analytic work beyond any individual's capacity. That is, the ideographic requirement of specific detail in such analysis excludes any possibility of scholarly achievement in splendid isolation. My own inspiration and instruction in this approach is deeply rooted in other people's field work and writing on specific times and particular events in particular places in the Amazon.

Susanna Hecht's (1985) integration of material properties of soils, trees, grasses, and beef cattle into the political economy and spatial parameters of Brazilian fiscal incentives for ranching and the politics of land use serves as a stellar model of the intersection of physical and social phenomena. Timmons Roberts' relation of subcontracting and other informalizing labor relations to the spatio-material requirements of the Carajás deposits and his subsequent work with Peter Grimes on the interactions between the economy and the ecology of the world system, Maria Celia Coelho's examination of the social and environmental effect of the rail line from Carajás through the Amazon jungles to the coast, and Maurilio de Abreu Monteiro's analysis of the material and energetic flows of the various minerals enterprises in the Amazon have all built on and elaborated these ideas.

Collaborative work with Denis O'Hearn comparing strategies of importing and exporting nations in the world aluminum industry at different moments of world-system history(Bunker and O'Hearn, 1992; Barham, Bunker, and O'Hearn, 1994) and discussing his work on the world systemic effects of technological innovation in the cotton textile industry helped me move from local to global perspectives. I benefitted enormously from lengthy discussions with Ty Priest during his research and analysis of U.S. strategies to acquire manganese. I learned a great deal as well from; Paul Ciccantell's comparison of Venezuelan and Brazilian responses to the Japanese strategies to transform world aluminum markets; Paul Gellert's analysis of the interactions between the rivers and ports of East Kalimantan, the collusion of Indonesian capital and the Indonesian state to control and profit from the extraction, transformation and sale of *Diptherocarp*, and Japanese capital, consumption, and state policy; and Jonathan Leitner's examination of struggles between Britain and the U.S., and then between interests in different U.S. regions to control world and American copper markets. These case studies greatly extend the reach and the specificity of this model, while at the same time demonstrating concretely and practically that attention to space and matter refines the empirical and theoretical bases not just of enviromental history and sociology, but of a broad range of other socially, political, and economically relevant fields of research.

As Paul Ciccantell and I worked through these issues, we noticed again the crucial role of technical economies of scale and huge increases in capital sunk in transport infrastructure, in reducing the cost of moving raw materials through space and so expanding the space across which cheap, bulky, raw materials could economically be moved. Making sense of the ways that the Japanese restructured and globalized raw materials markets, we had to look at earlier technological revolutions that caused huge, step-wise jumps in economies of scale in processing the bulkiest, cheapest raw materials and in their transport.

As we compared the access strategies and transport technologies of Amsterdam, Great Britain, the U.S., and Japan, we saw how technological innovations directly influenced by material features had led to new economies of scale in those industries that consumed the greatest volume of raw materials, and how these scale increases had accelerated depletion of the most proximate sources and therefore drove the search for the most voluminously consumed raw materials across ever greater spaces. Economies of scale thus created their own contradiction in the rising cost of distance across space; the reiterated solutions to this contradiction could only be acheived through even greater economies of scale in transport, which then drove further scale increases in consumption of raw materials, reiterating the contradiction anew.[14] The secular repetition of this cycle, each time expanded, suggests a model of reiterated scale solutions—with their attendant spatial fixes—as a mechanism for the secular movement of the world system toward globalization.

These scale economies in raw materials transport and transformation have preceded each of the expansions of commercial space that Arrighi (1994) identifies as components of each transition between systemic cycles of accumulation. Arrighi explains these expansions primarily as the combined response of states and finance to overaccumulation of capital in the trade dominant nation. In this regard, he follows David Harvey's (1983) explanation of the "spatial fix" or the geographic expansion of capital as the solution to the overaccumulation and consequent devaluation of capital that emerge from the "internal dialectic of capital".

14. See Haydu(1998) for a model of reiterated solutions.

Analysis of the processes that have linked each of the Amazon's extractive economies to the changing demands of the world economy drives us to elaborate another affirmation that Harvey adopts from Marx; that technology mediates between society and nature. In other words, we attempt to integrate the spatial and material history of world raw materials markets and transport with the financial and political dynamics of world capital. Technology and infrastructure can mold space and matter only with the direct intervention of politics and finance.

The history of the Amazon shows that technology—both in transport and in production—is cumulatively expansive in its scale, in its power, and in its cost. Comparative analysis of the rubber, iron, and aluminum economies in the Amazon suggests that core firms and states devise, promote, finance and implement these technologies as part of their strategies to achieve trade dominance. To achieve the competitive advantages and economies that trade dominance requires, these technologies must conform to the material characteristics and locations in space of the raw materials whose transportation and transformation they cheapen and expand.

In this sense, the materio-spatial features of extractive peripheries set boundaries on the core nation's technical innovations. This materio-spatial determinancy of the periphery is negated by the political and economic subordination of the periphery to these new economies of scale. Each extractive episode involved the transport of greater volumes of goods—from spices to turtle oil to fine woods to rubber to iron ore—more cheaply over greater distances. The increasingly costly investments in local transport infrastructure have devolved more and more upon the local economy. Carajás, dependent on the global transport of an ore whose huge consumption in the world market rests on its very low value to volume, is but the latest, and most dramatic, example of how transport technologies devised to solve the tension between scale and space, promote globablization by cheapening ton/miles at the suppliers' expense. This cheapening is essential to competitive capital's procurement of raw materials over an ever broader part of the globe.

To understand the spatio-material and technological expansions and intensifications underlying globalization, we must simultaneously specify the geographically differentiated materialization of space into the topographic, hydrologic, geologic, and climatologic attributes of different locations as these determine the quality and character of the raw materials through which they participate in the world economy. The essential obverse of materialization of space lies in the spatial differentiation of matter as manifest in the location of different use values.

Both the materialization of space and the spatial location of matter impinge on human economic activity according to the technologies of extraction, production and transport. The specific physical and chemical properties of Amazonian rubber, for example, made it more amenable to the technical manipulations of the industrial technologies that dominated the mid–19th century world market. The utility and abundance of that spatially particular type of rubber meant that most of the technological innovations to improve and extend the industrial uses of rubber were researched, designed and implemented around the specific chemical and physical properties of Amazonian rubber. Similarly, just as the technologies that drove the mid 19th century expansion and progressive mechanization of iron extraction and smelting were developed in response to and interaction with the physical properties and topographic locations of the huge iron ore deposits around the Great Lakes, the potential profits that motivated the huge investments in Carajás reflected the physical and chemical compatibility of the deposit with the most profitable technologies and the accessibility of the deposits to the most economical forms of transport. In other words, the technologies of transport and transformation of the most voluminously used raw materials have expanded and grown in power in simultaneous interaction with the scale increases in the world economy and with the materio-spatial attributes of specific local sources.

From this perspective, globalization must eventually collide with inexorable natural limits of both space and matter. At the local level, the inequality between extractive and productive economies (Bunker, 1985; Bunker and Ciccantell, 2001), and the unbalanced flow of matter and of energy from the extraction to production which informed my analysis of the developmental and environmental effects of the Amazon's rubber boom and bust (Bunker, 1982), can only become greater as economies of scale approach these natural limits. At the global level, the internal dialectic of capital has driven each systemic cycle of accumulation first to site-specific or local depletion of the technically most accessible raw materials and then to the overaccumulation and devaluation of capital in the dominant economy.

Thus far, each episode of these material and financial dilemmas has been resolved by a spatial fix that has incorporated new types and deposits of raw materials into new technologies and infrastructures of transport. The investments in the transport systems required to incorporate these new sources of material into the world market also provide avenues for the extension of commerce and investment into expanding global markets. As the most voluminously used, lowest value-to-volume raw materials are introduced into global trade, the potential for future crises of resource depletion and capital devaluation increases, while the potential for spatial fixes through discovering large new deposits in more distant places, decreases. is eliminated. The next great crisis of capital may result as from spatio-material constraints rather than from financial responses to overaccumulation and devaluation. The question then will be whether the states, firms and sectors—whose strategic collaborations to achieve national dominance of world trade by investing in new scale economies have led to this crisis—will be able to invent new forms of collaboration that do not require material intensification or spatial expansion.

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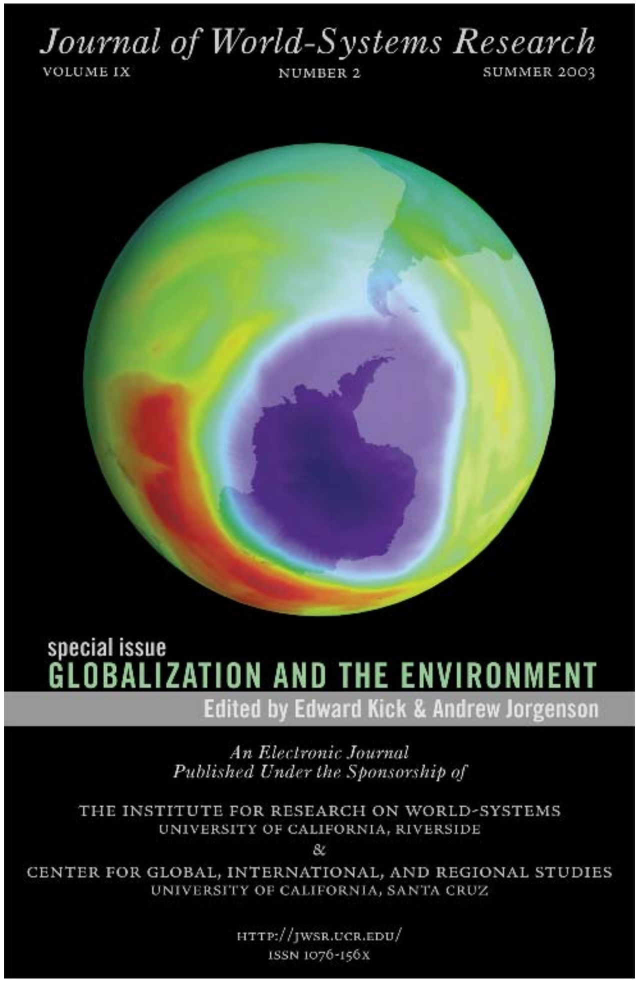

Exporting the Greenhouse: Foreign Capital Penetration and CO_2 Emissions 1980–1996

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ABSTRACT

This research examines the impact of foreign investment dependence on carbon dioxide emissions between 1980 and 1996. In a cross-national panel regression analysis of 66 less developed countries, we find that foreign capital penetration in 1980 has a significant positive effect on the growth of CO_2 emissions between 1980 and 1996. Domestic investment, however, has no systematic effect. We suggest several reasons for these findings. Foreign investment is more concentrated in those industries that require more energy. Second, transnational corporations may relocate highly polluting industries to countries with fewer environmental controls. Third, the movement of inputs and outputs resulting from the global dispersion of production over the past 30 years is likely to be more energy-expensive in countries with poorer infrastructure. Finally, power generation in the countries receiving foreign investment is considerably less efficient than within the countries of the core.

INTRODUCTION

Most of the work on global warming to date has been done by physical scientists. In general their focus has been on detailing the chemistry and physics involved, and demonstrating that human emission of compounds essential to the process have been growing (e.g CO_2, Methane, CFC's, CHFC's). At the same time, their work has proven that average global temperatures have indeed been rising at rates predicted by their theoretical expectations (see the publications of the *Intergovernmental Panel on Climate Change*, esp Houghton *et. al.*, 2001).

The precision of this scientific effort has been extremely helpful in both legitimizing and popularizing the vital importance of the issue, and succeeded in raising it to the highest levels of global political concern. However, the dominant contribution of the physical scientists has distracted public attention from the potential contribution of the social scientists.

Physical science can explain the thermodynamic issues of atmospheric heat entrapment, identify the chemical compounds responsible, and even isolate the kinds of human activities responsible for creating those compounds. However, experts in these questions cannot address the political, economic, and social forces that explain the **choice** of systems, machinery, and locations employing those compounds. The logic explaining these most fundamental choices can

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only be understood by using the analytical tools of the **social sciences**—tools untaught to practitioners of the physical sciences. At a time when wars over the control of oil are more frequent, it is particularly important that we understand the social forces behind both the thirst for oil and the atmospheric warming following its use.

Fortunately, a growing number of social scientists working within a world-system perspective have begun to address this disciplinary gap (Bergeson and Parisi, 1997; Burns, Davis, and Kick, 1997; Grimes, Roberts, and Manale, 1993 and in this issue; Grimes and Roberts, 1995; Roberts and Grimes, 1997). After a brief review of the contributions from the physical scientists we will evaluate these recent contributions from world-system theorists and show how our work here both extends and supports their findings.

GLOBAL WARMING AND ITS COST

Daily changes in weather have accustomed all of us to the instability of temperature over the short run. But these daily and seasonal fluctuations tend to cancel out; leaving the impression that Earth's "thermostat" is always the same. The reality is far more subtle, of course. Earth's surface temperature is the outcome of energy flows that are dynamic, sensitively re-adjusting to a fluid balance of forces. The incoming warmth from the sun and the internal heat from the molten core beneath the mantle are continuously being radiated out into space, and the difference between these rates of warming and cooling creates the surface temperatures we must cope with. The atmosphere ultimately governs this race between heating and cooling by acting as a "valve" regulating the rate of heat loss from infrared radiation into space, and the size of this valve—the "clarity" of the infrared "window"—is mainly due to CO_2. Along with Methane, CFC's, and CHFC's, CO_2 captures heat, acting like a gaseous blanket over the planet. Although heat (infrared light-radiation) still works its way out through this chemical blanket, the blanket slows its progress enough to retard cooling and raise the global surface temperature.

If it were not for naturally occurring levels of atmospheric CO_2 in the past, the surface temperature of our planet would be below freezing (–18c), liquid water would not exist, and life as we know it impossible (Cowen 1995). Corroborating evidence is provided by the dating of sequential strata of seabed sediment indicating that periods of glaciation are actually the norm, while inter-glacial times like the last 10,000 years are the ***exception*** (e.g. Monastersky 1996a & b).

It is a delicate balance. Evidence from the fossil record and Antarctic ice cores reveal that levels of atmospheric CO_2 have risen inversely with periods of glaciation for at least the past 100,000 years. These same ice cores show that levels of

atmospheric CO_2 have risen 27% during the period 1800-1990, from 280ppm to 355ppm (CDIAC 1991, 1993, 1999, 2001). The increase in levels of CO_2 since 1800 is almost certainly due to human activity—massive deforestation during the 19th Century added to in the 20th by the burning of fossil fuels. Today all automobiles, planes, and ships burning fossil fuels emit CO_2, along with all coal or oil fired electric generators. Hence almost all of the machinery used in modern production contributes to CO_2 emissions.

The Intergovernmental Panel on Climate Change has reached consensus that global warming is already well along (Houghton, 1990, 1992, 2001). Temperatures in the northern hemisphere have shot up dramatically since 1900, well above their average for the previous five centuries. Glacial ice-packs are retreating at unprecedented rates (Jacobs *et. al.*, 2002; Meier and Dyurgerov, 2002), while plants and butterflies have been documented moving higher up mountains and further north (Peters and Lovejoy 1992).

Warming implies a general movement toward the poles of the climates appropriate for the major food crops (wheat, rice, and maize). For the majority of plants not under human cultivation, the polar shift in climate may outrun their ability to migrate, leading to their extinction along with the life forms dependent on them (Peters and Lovejoy 1992; Etterson and Shaw 2001). Melting ice suggests rising sea levels, which satellite data now confirm (Jacobs *et. al*. 2002). The remaining glacial ice, if fully melted, would add another 250 feet (Robinson 1993: Chapter 9). While we are yet far from that point, a rise of only one or two feet would permanently flood the currently arable land around the Nile, and has been estimated to be able to cut agricultural production globally by as much as 20 percent. Further, rising sea levels pose the potential for flooding important ports and coastal cities, as well as entire pacific island nations. Finally, climate models predict more frequent storms having higher wind-speeds with increased warming, implying corresponding increases in deaths and infrastructural damage. Because the global population is growing, and most of that population lives near rivers and seacoasts, the mortality figures could become truly staggering, as well as the costs of repair.

THE SOCIAL STRUCTURE OF WARMING

Fossil fuels are consumed throughout the activities of daily life, being used to power homes, businesses, and transportation. But the support for this consumption requires an expensive infrastructure of pipelines, wires and roads, as well as the money to pay for the fuels themselves. Consequently the use of these fuels reflects the distribution of global income and political power, and is just as highly polarized. In 1995, 80 percent of the world's emissions of CO_2 emerged from the countries of the core, with the United States ***alone*** accounting for 27 percent (WRI 1996). Further, until recent decades this polarized distribution of fuel consumption also tracked economic output (Burns, Davis, and Kick 1997). That is, both the overall volume of carbon and the emission of pounds of carbon per dollar of GDP was greatest among the countries of the core and lowest among those of the periphery, appearing to show that energy ***efficiency*** was also higher among the poor than the rich.

However, recent research has demonstrated that this apparent link between production output and energy efficiency was a transient phenomenon, found in the data for the 25 years following the second World War, but falling quickly apart during the decade of the 1970's (Roberts and Grimes, 1997; Roberts, Grimes, and Manale in this issue). Even though core countries continue to be the greatest contributors to the overall **volume** of atmospheric CO_2 (Burns, Davis, and Kick 1997), by 1990 the **ratio** of CO_2/GDP has grown to vary by nearly one **hundredfold**, while emissions of carbon dioxide per capita varies now by over two **thousandfold** (WRI 1992; CDIAC 1991/1993). Even among nations with the same GDP *per capita* the ratio varies considerably.

This growing divergence in CO_2/GDP since the 1970's appears as a dramatic ***increase*** in energy efficiency within the core against an equal ***decrease*** in efficiency within the semi-periphery and upper periphery (Roberts and Grimes, 1997). At the same time, the variation among those countries with dropping efficiency has itself grown rapidly. Previous research has also demonstrated that in 1990, holding world-system position constant, the least efficient producers were also the most politically repressive. They had the fewest political freedoms, the weakest unions, and the strongest internal military presence (Burns, Davis, and Kick, 1997; Roberts, Grimes, and Manale here). It was argued there that the recent flight of production capital away from the unions and regulations of the core and into the cheaper locations provided by the repressive regimes of the Americas and East Asia was the key unlocking both the increasing carbon efficiency in the core and its drop among some members of the semiperiphery.

To summarise, world-system research on CO_2 production to date has found that the volume of energy consumption and thus CO_2 production continues to track world-system position, being greatest in the core, intermediate in the semi-periphery, and lowest in the periphery (Burns, Davis, and Kick 1997). However, since 1975 the production efficiency (as measured by the ratio of CO_2/GDP) within the core appears to be growing while that within the semi-periphery is falling, presumably due to the relocation of manufacturing away from the high wages of the core toward the lower and more politically repressed wages found in the semi-periphery (Roberts and Grimes 1997; Roberts, Grimes, and Manale 1993 and here). While this previous work has suggested that capital flight out

of the core may have been the mechanism responsible for the rise in the ratio of CO_2/GDP observed over time in the semi-periphery, no research has yet sought to validate this implication by actually tying the flow of investment capital to observed changes in the volume of output CO2 over time. After a brief theoretical review, that will be the empirical project to which we will ultimately turn.

THE GLOBALIZATION OF PRODUCTION

The past twenty five years have witnessed a massive shift in the geographical distribution of production from the core to less developed areas of the world economy (Sassen 1996), as transnational corporations searched for lower wages, closer proximity to markets and raw materials, and a way to diffuse the power of labor. Less developed countries became "parts suppliers" to the global economy, which has given rise to global commodity chains (Gereffi and Korzeniewicz 1994). Facilitated by increasingly efficient, low cost transportation, it became cost effective to distribute the production of individual components of a given product (i.e. autos) across several geographically distant locations, have the parts assembled in another country, and then re-shipped to markets throughout the world for sale. While this globalization of production may increase the profits of transnational corporations, it also increases the amount of international transportation, which accelerates the consumption of fossil fuels.

This global relocation of production was fueled by a dramatic expansion of foreign investment. As Beer and Boswell explain (2002: 31):

> …foreign direct investment has dramatically increased in importance over the last two decades, and is currently the primary source of resource flows to developing nations (Froot 1993; Tsai 1995). In 1998, FDI surpassed all other forms of lending as a source of foreign capital to developing nations (WDR [World Bank] 1991). In 1982, the total value of global inward FDI stock stood at almost 6 billion (US$), by 1990 that figure had reached 1.7 trillion (US$), and by 1999 it had reached 4.7 trillion (WIR 2000). The ratio of world FDI stock to world GDP increased from 5% in 1980 10 16% in 2000 (WIR [World Bank] 2000).

The countries competing for and receiving this capital flight out of the core were primarily located in East Asia and Latin America (geographically), and in the semi-periphery and upper periphery (structurally). But although this move cheapened the labor and political costs of production, it increased the actual consumption of energy (and carbon emission) used in that production.

There are several reasons to expect that production outside of the core would be more energy consumptive than inside the core. Most important is the relatively poor infrastructure. States outside of the core lack the tax revenues to finance much new construction or keep up repairs on the old. So roads are less often paved or maintained, rail service spotty, and the electricity grid fragile and prone to frequent blackouts. The trucks and rolling stock using these facilities are themselves second or even third-hand, whether state or privately owned. Finally, power generation facilities use both older equipment and the cheapest fuels, which are often the most polluting. For all of these reasons it takes more fuel to move raw materials in and finished products out of factories outside of the core than those within, and providing power to those factories is more polluting (including productive of CO_2) than it is within the core.

So while the *motivation* for capital to leave the core during the 1970's and 1980's may have been mainly about lower wage and raw material costs, a side-effect was to increase both the volume and per dollar amount of CO_2 introduced into the atmosphere by the countries in the semi-periphery and periphery.

Yet before we can examine the data, one last argument needs to be disposed of.

KUZNET'S GHOST

In 1955, Simon Kuznets wrote a now classic piece on income inequality around the world. In it, he observed that the cross-national data on internal income inequality then available appeared to sequentially rise and then fall when graphed against rising national wealth. Although the cross-sectional nature of the data prevented him from drawing any firm conclusions about change over time, he speculated that the phenomenon might be a reflection of just such a change. In particular, he suggested that the initial accumulation of capital required for long term development would generate the large inequalities observed in the middle-income countries. Meanwhile, the poorest countries were devoid of such accumulation altogether; and the richest had developed so many areas of accumulation and enough political complexity that sharp divisions in income had been smoothed out. Of course it is no coincidence that Kuznet's influential publication emerged during the intellectual boom period of modernization theory, which argued precisely that the world's wealthiest countries portrayed a future achievable to the world's poor.

Now, 50 years on, students of development have more realistically appreciated both the legacy of colonialism and its reincarnation in current market mechanisms. As a consequence the accumulation of capital and its effects on the quality of life are more typically understood to be ***global*** processes transcending international borders (e.g. Chase-Dunn and Grimes, 1995; Grimes, 1999; Kentor, 1998). Viewed from this more sophisticated perspective, the degrees of internal inequality, political repression, physical infrastructure, and other qualities of the political-economy of production are each attributes of an *international division of labor* that works for the accumulation of capital on a **global scale**—a true "world-economy." Hence the data pattern observed by Dr. Kuznets in 1955 would today

be interpreted quite differently: not as revealing the stages of an accumulation process across separate units (nation-states) but instead as revealing the geography of political repression within one single unit (the world-economy).

Despite this theoretical advance some—perhaps in ignorance of it—have sought to regress to Kuznets in order to explain a similar rise and fall in pollutants (expressed either as *per capita* or as *per unit GDP*) when nations are arrayed across measures of rising national wealth (Roberts and Grimes 1997). When Kuznets made his original assertions about the future of inequality within the sunny assumptions of modernization theory it implied to politicians that the "solution" was to do nothing, because the trajectory of national development (capital accumulation) would eventually lift all countries high enough up that income inequality would shrink automatically. Now, during a time of growing popular concern over the deteriorating state of the world's environment it may not be coincidental that a few authors (some affiliated with the World Bank) have found it soothing to suggest an analogous "environmental" Kuznets curve, with its comforting illusion that we need do nothing again but wait until "development" (again assumed to be an autonomous national process) restores balance with the biosphere anew.

Because Kuznet's speculation was informed by an erroneous theory, his predictions were equally wrong: today inequality among the middle-income countries is greater than ever. Hence it is with no surprise that Roberts and Grimes (1997) showed that from 1960–1990, the ghost of Kuznets as applied to environmental pollution was just as wrong as it was when applied to inequality.

THE METHOD AND DATA

Here the hypothesis that foreign investment has re-located many important sources of emissions from the core into the semi-periphery since 1980 is explored directly. We combined data sets on foreign investment and CO_2 emissions to see whether the two were linked in the ways we expected. More specifically, we wanted to see if the destinations of investments made in the past were the same as the places where CO_2/GDP is now the highest. As the tables below show, our expectations were supported fully by the data.

Panel regression analysis was used to estimate the effects of foreign and domestic investment on CO_2 emissions between 1980 and 1996. In this type of analysis, the lagged dependent variable is included as an independent variable. This method controls for prior states of the countries included in the analyses and controls for the possibility of reciprocal causality.

Countries included in the Analyses

We include only less developed countries in these analyses, which is a common practice in similar cross-national research on the effects of foreign capital penetration (Bornschier and Chase-Dunn 1978; Crenshaw and Ameen 1994; Dixon and Boswell 1996; Firebaugh 1992, 1996; Flegg 1979; Kentor 1998, 2001; Kentor and Boswell 2003). The basic argument is that the impact of foreign capital penetration is different for less developed countries than for developed nations.

We empirically define less developed countries as those nations with per capita GNP of less than $ 15,000 in 1980. It should be noted, though, that the results are not sensitive to this specific cut-off point. Similar results are found with lower values (e.g. $10,000) as well. A list-wise deletion of cases leaves 66 cases in the analyses. A list of these countries is given in Appendix A.

Variables included in the Analysis[1]

Dependent Variable

The dependent variable is the level of CO_2 emissions in 1996, which has been logged (Ln) to correct the extreme skewness of this measure. The data are taken from the United Nations (World Resource Institute 2000). We use absolute levels rather than CO_2 / GDP, because we are interested in assessing the impact of foreign capital penetration on the environment.

Independent Variables

Foreign Direct Investment Stocks / GDP (natural log) is the measure of foreign capital penetration included in most current analyses (Dixon and Boswell 1996; Firebaugh 1996; Grimes and Kentor 1998; Kentor 1998, 2001, Soysa and Oneal 1999) and indicates the extent to which foreign capital dominates the investment structure of the host economy. This variable is logged due to its skewed distribution. These data are provided by UNCTAD (1997).

Gross Domestic Investment / GDP is the rate of domestic investment in fixed assets plus note changes in inventory levels, and is provided by the World Bank (1999).

Trade / GDP is included as a control for a country's level of integration in the world-economy (Bornschier and Chase-Dunn 1985; Chase-Dunn 1975; Dixon and Boswell 1996; Firebaugh 1992, 1996; Grimes and Kentor 1998; Soysa and Oneal 1999). Data are taken from the World Bank (1999).

1. Descriptive statistics and correlations for all variables in the analyses are given in Appendix B.

Table 1 – The Effects of domestic and foreign investment on Total CO_2 emissions 1980–96

DEPENDENT VAR: CO_2 1996 (Ln)

	Model 1			Model 2		
INDEPENDENT VARS	***b***	***Beta***	**t**	***b***	***Beta***	**t**
FDI/GDP 1980 (Ln)	**0.71**	**0.32**	**2.36***	**0.79**	**0.36**	**2.52***
GDI/GDP 1980	0.01	0.04	0.28	0.01	0.02	0.13
Exports/GDP 1980	–0.03	–0.23	–1.59	–0.02	–0.24	–1.66
GNPpc 1980 (Ln)	0.01	0.003	0.02	–0.44	–0.19	–0.97
CO_2 – total (Ln) 1980	**0.65**	**0.55**	**4.22*****	**0.56**	**0.47**	**3.35****
Agriculture/GDP 1980				–0.03	–0.15	–0.66
Africa Dummy				–1.19	–0.21	–1.52
Constant	–1.46		–0.69	4.22		0.42
Adjusted R^2	**0.29**			**0.31**		
N	**66**			**66**		

***p<.05, **p<.01, ***p<.001 (two-tailed tests)**

GNP per capita (natural log) is a measure of a country's wealth and, therefore, an indicator of level of development (Arrighi and Drangel 1986). Data are provided by the World Bank (1996, 1999).

Agriculture, % of GDP, controls for the structure of the host economy. Agricultural production typically generates less CO_2 than the industrial sector of the economy.

Total CO_2 Emissions 1980 (natural log) is the lagged dependent variable. It is included in the analyses to control for the prior state of the dependent variable and for the possibility of reciprocal causality. This variable, too, has been logged to correct the skewness of the distribution.

Africa is a dummy variable that controls for geographical differences in the global economy. This variable is coded "1" if the country is on the African Continent, and "0" if not.

RESULTS

The primary finding of these analyses is that foreign capital penetration in 1980 has a significant positive effect on growth in total CO_2 emissions between 1980 and 1995 in less developed countries, net of the other independent variables. We find no systematic effect of domestic investment on total CO_2 emissions over the same period.

The results are given in Table 1. Two models are presented. In Model 1, total CO_2 emissions in 1996 is regressed on gross domestic investment, foreign capital penetration, trade, GNP per capita, and total CO_2 emissions, all measured in 1980. Model 2 adds the additional control variables of agricultural production, and the Africa dummy, also measured in 1980. Both analyses were tested for outliers and influential cases, but none were found. Variance Inflation Factors (VIF) were also examined for possible effects of multi-collinearity. VIF values for all variables were within acceptable limits.

The coefficients for models 1 and 2 are similar, indicating that the two additional control variables included in the second model do not have a significant impact on the relationships examined in the first model. Therefore, we discuss the findings for the more comprehensive model two. Foreign capital penetration in 1980 has a significant positive effect on change in total CO_2 emissions between 1980 and 1996 (beta = .36). Gross domestic investment, however, does not have a significant effect. The only other significant effect is that of the lagged dependent variable. The coefficients for two of the control variables, trade/GDP and the Africa dummy, while not significant, are more than twice their standard errors.

DISCUSSION AND CONCLUSIONS

The central finding of these analyses is that *dependence on foreign capital accelerates* the rate of growth of CO_2 emissions in less developed countries. This effect is driven by the global diffusion of production that has occurred over the past twenty-five years in several ways. First, foreign investment in LDCs is concentrated in energy consumptive industries. Second, the "new" logic of commodity chains, while cost efficient, increases the amount of transportation involved in the overall manufacture of goods. Third, the countries to which production has been transferred have poor domestic infrastructures, which result in less energy efficient production. The contribution of domestic capital is negligible, because only *foreign* capital can purchase the equipment required for highly automated (and energy-consumptive) production. Finally, transnational corporations may be less likely to invest in pollution controls for production in less developed countries, which tend to have fewer environmental controls.

These results support the findings of other research which notes an increase in energy efficiency measured as CO_2/GDP in the core and a fall in that same efficiency within the periphery during that same 1975/1980–2000 period (Roberts, Grimes, & Manale 2003).

It is important to consider the policy implications of this study. It is clear from these results that controlling CO_2 emissions requires a global perspective. It is not sufficient to address the generation of greenhouse gasses in the core, without regard to whether production of CO_2 has simply been transferred to, and possibly accelerated in, less developed countries.

Finally, this work suggests at least two areas for further research. First, it would be useful to examine the types of investments that have traveled to less developed countries in the last two decades and how this global diffusion of production is reflected in energy consumptive industries, less efficient production and greater environmental impact. Second, cross- national research doesn't provide much insight into country specific processes. It would be worthwhile to study the ways in which the dynamics of foreign investment play out in a given country over time, with a focus on the ways in which political policies are shaped by these investments.

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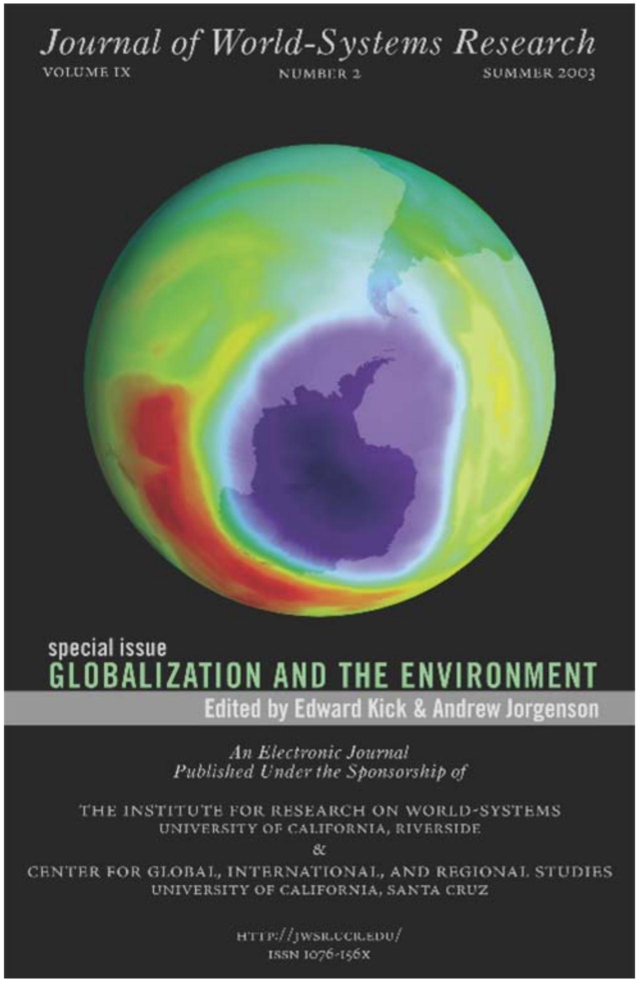
Appendix A – Countries included in the analyses: N=66

Algeria
Argentina
Bangladesh
Barbados
Benin
Botswana
Brazil
Burkina Faso
Burundi
Cameroon
Central African
Chad
Chile
China
Colombia
Comoros
Congo, Rep.
Costa Rica
Cote d'Ivoire
Dominican Rep.
Ecuador
Gabon
Gambia, The
Greece
Guatemala
Honduras
Hong Kong, China
India
Indonesia
Iran
Italy
Jordan
Kenya
Korea, Rep.
Madagascar
Malawi
Malaysia
Mali
Malta
Mauritania
Mexico
Morocco
New Zealand
Nicaragua
Niger
Nigeria
Oman
Panama
Papua New Guinea
Philippines
Rwanda
Saudi Arabia
Senegal
Seychelles
Singapore
South Africa
Sri Lanka
Swaziland
Thailand
Togo
Trinidad and To
Tunisia
Turkey
Uruguay
Venezuela
Zambia

Appendix B – Descriptive Statistics and Correlations for Variables in the Analyses: N=66.

	Mean	S.D.	GDI 1980	FCP 1980	Exports 1980	GNP pc 1980	CO2 1980	Agric 1980	Africa
CO2 1996, total (Ln)	8.73	2.87	.20	.13	-.07	.24	.53	-.34	-.33
Gross Domestic Investment/GDP 1980	25.41	7.77		.44	.49	.36	.25	-.47	-.14
Foreign Capital Penetration 1980 (ln)	1.66	1.29			.57	.30	-.14	-.38	.14
Exports / GDP	35.55	31.44				.43	-.07	-.47	-.06
GNP per capita (Ln)	7.12	1.28					.42	-.84	-.53
CO2, Total 1980 (Ln)	14.38	2.41						-.50	-.47
Agriculture/GDP 1980	20.95	13.68							.45
Africa Dummy	0.39	0.49							



ABSTRACT

Carbon dioxide is understood to be the most important greenhouse gas believed to be altering the global climate. This article applies world-system theory to environmental damage. An analysis of 154 countries examines the contribution of both position in the world economy and internal class and political forces in determining a nation's CO_2 intensity. CO_2 intensity is defined here as the amount of carbon dioxide released per unit of economic output. An inverted U distribution of CO_2 intensity across the range of countries in the global stratification system is identified and discussed. Ordinary Least Squares regression suggests that the least efficient consumers of fossil fuels are some countries within the semi-periphery and upper periphery, specifically those nations which are high exporters, those highly in debt, nations with higher military spending, and those with a repressive social structure.

Social Roots of Global Environmental Change: A World-Systems Analysis Of Carbon Dioxide Emissions*

J. Timmons Roberts
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Jodie L. Manale

INTRODUCTION

Pollution has long been understood to threaten local populations and ecosystems, but there is now a broad awareness that human societies are altering the global climate through the emissions of carbon dioxide and other "greenhouse" gasses. As the National Research Council pointed out, "to adequately address the human dimensions of global change will require analyses at the global scale" (Stern, Young and Druckman 1992: 178). We believe that world-systems theory provides such an analytical scale; integrating global scope, broad historical perspective, and well-developed empirical techniques. Our broader research project is to link sociological insights on global economic restructuring and the "New International Division of Labor" with levels and types of environmental destruction in different parts of the world stratification system. We here apply world-systems analysis in an attempt to locate the social factors underlying one of the most important environmental outcome: the CO_2 "intensity" of pro-

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duction within countries, as defined by the quantity of CO_2 released per unit of economic output.

There is a strong correlation between the total economic output of nations (as measured by their Gross Domestic Product) and their carbon dioxide emissions. Big economies pollute more, and the United States is by far the world's largest emitter of carbon dioxide, releasing 23 percent of the world's emissions from fossil fuel combustion, nearly twice that of any other nation.[1] For years, research on global warming was dominated by physical scientists who tended to assume that CO_2 emissions were a linear by-product of economic development. Implicit within this assumption was the notion that there was a thermodynamically fixed connection between the economic value of the items created within an economy and the amount of energy (hence CO_2) needed to create those items. Such a simplifying assumption, however, has the effect of sweeping social-scientific inquiry out of analyses of global warming altogether, because physical scientists consistently reduced the complexities of global production to thermodynamic and physical constants.

But this relation is not, in fact, linear at all. A quarter century ago Mazur and Rosa (1974) and Buttel (1978) showed that energy use is not firmly tied to indicators of social well-being (see also Rosa and Krebill-Prather 1993). That the relation between economic growth and energy use (and resulting pollution) is not cast in stone was shown by West Germany in the 1980s: while its economy grew at an average annual rate of 2.1 percent during that decade, West German emissions of carbon dioxide fell by an average annual rate of –1.2 percent (World Bank 1992b: 204, 221).

These deviations from general trends serve to show that at root the generation of greenhouse gasses is not solely determined by technology or thermodynamics but also from human choices about the organization of production and consumption. Some economies are far more "efficient" than others at producing "wealth" for the environmental cost. For example, in 1997 the United States produced 75% more CO_2 per unit of GDP than did the UK or Japan, and 3.5 times as much as Switzerland.[2] Among countries with lower incomes per capita, Trinidad and Turkmenistan produced over 12 times the carbon dioxide per unit of GDP as did Uruguay and Kenya, and over 20 times more than Sri Lanka, Uganda and Mozambique.

1. World Bank 2001, data is for the latest year available there, 1997. On a per person basis, the U.S. emits five times the global average, and nearly 20 times the average for the "low income" countries.

2. These figures are adjusted by Purchasing Power Parity, by the World Bank 2001.

We seek here to apply the insights of political-economy to understand why carbon emissions should vary so widely. By doing so we hope also to contribute to the decades-long debate about whether population, affluence or inefficiency are the most important factors at the root of the world's great environmental problems.[3] This attention to carbon intensity (inefficiency) tells us some things the other approaches cannot: there is much variation to be explained, and the patterns may have important lessons on how to make our economies more efficient.

By coincidence, our "intensity" approach also has a new policy relevance. It happens to be convenient for the current U.S. administration, because it appears to shift attention away from that nation—the biggest volume CO_2 emitter—toward less significant countries. After U.S. National Security Advisor Condoleezza Rice told EU members in spring 2001 that the Kyoto treaty to address climate change was "dead" without U.S. participation, the Bush administration had to provide an alternative plan to address the problem. In February, 2002, President G.W. Bush proposed his "New Approach on Global Climate Change" plan in response to the treaty, and provided a new benchmark by which America offered to measure its own progress on the issue. He "committed America to an aggressive new strategy to cut greenhouse gas intensity by 18% over the next 10 years."[4] The White House argued that:

> The President's Yardstick—Greenhouse Gas Intensity—is a Better Way to Measure Progress Without Hurting Growth. A goal expressed in terms of declining greenhouse gas intensity, measuring greenhouse gas emissions relative to economic activity, quantifies our effort to reduce emissions through conservation, adoption of cleaner, more efficient, and emission-reducing technologies, and sequestration. At the same time, an intensity goal accommodates economic growth.[5]

3. This is sometimes referred to as the Paul Ehrlich-Barry Commoner debate, and many authors refer to Commoner's I=PAT (environmental Impact=Population x Affluence x Technology) formulation. For recent reviews, see Bell 1998; Dietz and Rosa n.d.; and much other work by Eugene Rosa and collaborators. Our term CO2/GDP is algebraically equivalent to the T (technology) term in the IPAT model. While almost all previous authors have left the T term as a black box, our objective here is to begin to open that box.

4. White House, 2002a. The President promised that "If, in 2012, we find that we are not on track toward meeting our goal, and sound science justifies further policy action, the United States will respond with additional measures that may include a broad, market-based program as well as additional incentives and voluntary measures."

5. White House. 2002b.

Further, they argued that "Greenhouse gas intensity is a more practical way to discuss goals with developing countries, since carbon free technologies are not yet in place."

This article examines the world as measured by The President's Yardstick—examining patterns of greenhouse gas intensity around the world to attempt to explain variation in who emits how efficiently. Despite coinciding with that measure now, the current analysis was conceived of ten years ago to better understand how social organization and the rapid movement of capital was affecting CO_2 emissions. We acknowledge that other indicators more closely reflect ethical arguments on what is a *just* level of emissions, such as per capita or historical accounting of contributions to the climate change, but none reflects as well the efficiency of nations in terms of economic production vs. environmental cost.[6] While we believe carbon intensity has great potential to provide crucial insights for analysis and policy, such an index is no basis for an international agreement on climate change, since it addresses neither a nation's total impact on the atmosphere nor the savage inequality in who has created the problem and who will suffer its impacts.[7]

It is our goal here to uncover some of the social forces influencing national carbon intensity. To do so we need to characterize societies in terms of their CO_2 intensity, discerning which countries' economies are more and less efficient, and discover why. This exercise therefore has explicit policy implications in revealing the impact of social structures and national economic strategies on the output of the most important greenhouse gas.

To understand the relationships linking social forces and CO_2 emissions we must address several questions: First, are there links between a country's CO_2 emissions and its position in the global stratification system (its "world system position")? Second, are there other structural forces in the world-system such as relations of debt, levels of export dependency and types of exports which influence the emission of greenhouse gasses? Finally, when controlling for the effects of World-System Position and external linkages, how much do a country's internal class, economic and political structures also affect its emissions? For example,

6. There is now a huge literature on this topic, e.g. WRI 1990, page 17–19; CDIAC 1991, 1993; and more recently Neumayer 1999; Athanasiou and Baer 2002; we also refer readers to the websites of Climate Equity Observer, US, the Global Commons Institute, UK, the Center for Science and Environment, India, Eco-Equity Institute, US, and our forthcoming work, Roberts and Parks *forthcoming*.

7. Roberts 2001.

are the countries which deny basic human and political rights also those which permit greater destruction of the natural environment?

Until recently, a relatively small group of sociologists had made important attempts to bridge political economy and environmental issues (e.g. Schnaiberg 1980; Grimes 1982, Foster 1994; O'Connor 1989; Buttel 1992; Bunker 1985; Gould et al. 1996; Rudel 1989). Schnaiberg and O'Connor have advanced the useful idea that capitalism and national governments are on a "treadmill of production," which requires economic growth for their support and legitimation, and which is inevitably unsustainable (Schnaiberg 1980; Schnaiberg and Gould 1994; O'Connor 1973, 1989). However for decades writing in the world-system tradition ignored links between that system and the natural environment which supports it (see Smith 1993; Chew 1995; and review in Roberts and Grimes 2001; an exception was an earlier special issue of this journal). Like much of sociology, the paradigm therefore implicitly took what Dunlap and Catton (1994) called the "human exemptionalist" approach—that humans are exempt from ecological laws affecting other species. Clearly we are not.

A substantial theoretical exploration of how the internal and external conditions of countries might be related to their CO_2 intensity is necessary before we can move on to empirical testing. Our theoretical exploration builds from central world-system works. We focus on the crucial role of political repression and environmentally harmful policies in poorer countries' attempts to compensate for inadequate infrastructure and technology, and distance to major consumer markets. We then explore the validity of our hypotheses using OLS regressions in a cross-sectional analysis of 154 countries. Here we limit ourselves to attempting to explain carbon emissions from its main source: burning fossil fuels in production and commercial transportation, by governments and in private consumption.[8]

WORLD-SYSTEMS THEORY AND THE GLOBAL ENVIRONMENT

World-systems analysis evolved out of efforts over the past fifty years to explain how and why some countries in the world economy have been able to grow in power and wealth while others remain trapped in apparent stagnation

8. Industrial CO_2 figures also include emissions from cement manufacture and gas flaring, but these normally represent only small percentages of the total (Marland and Rotty 1984). See Appendix A for variable descriptions. Elsewhere we examine CO_2 emissions from deforestation, and we also undertake some time-series analyses, including a current effort to push back the present findings.

(e.g. Braudel 1981; Wallerstein 1974, 1979; review by Shannon 1996). It has four central postulates. First, the current world economy took on its defining features in Europe between 1500 and 1650 (but see Frank and Gills 1993). Second, among these features are a stable tri-part international stratification system of core, semi-periphery, and periphery through which individual countries may move (up or down), but which itself has not changed. Third, the ability of countries to achieve upward mobility is constrained by their trade relations with the world economy and their geo-political role and power, which together condition their structural location within the hierarchy (see e.g., Evans, Rueschemeyer and Skocpol 1985; Gereffi and Wyman 1990). Finally, this structural location—their world-system "position"—plays an important role in shaping their class structure and internal political battles. These last two postulates define world-system theory's relevance for understanding both national environmental policies and levels of damage by country (see Chase-Dunn and Grimes 1996; Roberts 1996a; Roberts and Grimes 2002).

Specifically, world-system theory asserts that the historical legacy of a country's "incorporation" into the global economy has a critical impact on the avenues of development available to it (e.g. Wallerstein 1979; Chase-Dunn 1989). This legacy helps to shape the types of products it makes (and which commodities are traded and with whom), the conditions for both capital and labor, as well as its global power *vis-à-vis* other nations. These elements in turn affect governmental policies towards the environment, decisions by firms within countries, and shape the life conditions of its peoples.

We do not believe a country's position in the hierarchy of nations (its "World-System Position" or WSP) alone can explain environmental outcomes since as we will see below, much variation exists between CO_2 outputs of countries at the same WSP level. However when combined with other critical variables on both external and internal features of a country, including WSP in cross-national analysis allows us to examine important patterns in the global stratification system. As difficult to operationalize as class and stratum, we chose for the present analysis a compromise measure of WSP which was based on a combination of qualitative groupings in the classic works (into core, semiperiphery and periphery), GDP per capita, and predominance in global trade (combining Terlouw 1992's indexes; see Appendix A). Predominance in global trade is roughly proportional to the total size of a country's GDP, which Van Rossem (1996) recently found to be the best simple proxy for WSP. WSP as operationalized here is strongly (but not perfectly) correlated with a country's wealth, as measured by GDP per capita (r=.774) and we often use WSP as a synonym for wealth. As cross-checks, we compare the value of these indices of global power.

A central expectation of this research is that behind the dual restraint of workers and environmentalists within each country lie the interests of local ruling classes, transnational corporations, and governments in sustaining both the profitable structures of internal production and the links between these structures and the world economy (Roberts and Thanos 2003). We expect that many countries in the semi-periphery and periphery with the highest levels of CO_2 emission per unit of economic output (as measured by GDP in U.S. dollars) are those specializing in exporting undervalued natural resources or manufactures based on cheap labor, exploiting both in a climate where business is relatively free of government regulation (see Ciccantell 1994; Kennedy 1993). But as we will see below, the semiperiphery is an extremely diverse category. In their attempts to spur economic growth and improve their World-System Position, some states have actively solicited highly-polluting industries fleeing higher costs and environmental regulations instituted in the core rich countries since 1970 (Covello and Frey 1990; Buttel 1992; Roberts and Grimes 1995; but see also Leonard 1988; Low and Yeats 1992; Pearson 1987; and the ongoing debate in the Journal of Environment and Development). Others have taken much "cleaner paths of development" than others, specializing in tourism, services, or higher technology.

As Vernon (1993) pointed out, to understand a country's willingness or hesitance to participate in global environmental agreements one needs to pay attention to the structure of the state and its dependence on the "polluting elites" that are tied to these export sectors (see Roberts 1996a,b). To this we would add that one must examine a country's level of dependence on foreign capital and how that capital was obtained (through private or public loans, grants or direct investment) in order to understand its impact on environmental protection policies (see Roberts 1996b). Some of these influences are contradictory. Though tightly linked, in our analysis we wish to explore the ability of internal and external variables to predict national carbon intensity.

CORE PRODUCTION AND CO_2 FROM FOSSIL FUELS

Though there is important variation, core nations in the world-economy are able to use the most advanced and capital intensive technologies to produce for world and home markets. Their economies also have largely shifted from manufacturing to services. In addition, though varying significantly, core laborers are the least coerced and highest paid relative to those outside of the core (Chase-Dunn 1989). This wage inequity between core and periphery has been exacerbated since World War II by a number of factors. These include but are not limited to the rise of monopoly capitalism, "Fordism," and the politics of trade union activism. In the United States this conjuncture both allowed for and compelled firms to pay higher wages, which in turn created a strong consumer base or domestic market. In addition, political organizations pursuing environmental goals are generally more active and tolerated in the core (see e.g. Dunlap, Gallup and Gallup 1993), making it often politically costlier to locate highly polluting production technologies there (but see Roberts 1996a,b). Despite higher wages, postwar production methods in the core could still often undercut lower paid but more labor-intensive production strategies found in poorer nations. Moreover, core firms' margins of profits and relative monopoly positions also made investments in energy efficiency and pollution control more viable.

While within the core the level of both wages and automation have been higher (as a national average) than countries in the periphery or semi-periphery, considerable variation still exists in their patterns of consumption. For example, despite increasing wages over the past 40 years, workers in Japan were guided by government policy into far greater levels of saving relative to consumption, in contrast to the same period in the U.S. (see e.g. Fajnzylber 1990a).

Just as there are important differences within the core at any one time, so are there shifting flows of investment and disinvestment over time throughout the system. Global restructuring of capitalism since the 1970's has seen a capital flight from the core to the semi-periphery and periphery, creating a "New International Division of Labor" with increasingly complex production taking place in poorer, lower-wage nations (e.g. Frobel, Heinrichs and Kreye 1981; Dicken 1998). This restructuring has had the effect of shifting some of the most polluting industries out of the core altogether, while raising unemployment and depressing wages within the core (see special issue of Environmental Economics in 1998, and other issues of that journal).

Energy use is high in the core because of the substitution of fossil fuels and other inorganic energy sources for human and animal power. Energy consumption is closely correlated with the size of a country's economy, and kilowatt hours of electricity consumed has often been used as a proxy for Gross National Product (e.g.Cook 1971; Humphrey and Buttel 1982: 154-8; Bollen and Appold 1993). At the same time, however, their advanced infrastructure—transportation, communications and production systems—makes it possible for both the social and physical machineries of production to be more thermodynamically efficient. This phenomenon is now discussed in terms of ecological modernization (Simonis 1989; Spaargaren and Mol 1992; Mol and Sonnenfeld 2000; Mol 2001). We expect that such efficiency has developed largely as the result of firm-level decisions to increase per-worker productivity, combined with government-level decisions to facilitate that production with improved infrastructure. Because efficiency gains are inevitably limited and the production of new efficient machines itself requires energy and materials, we do not believe that capital can entirely replace energy in this relationship.[9]

Although the restructuring of the global economy has had an uneven effect on the disciplining of workers and political activists in the core (e.g. de-industrialization and high unemployment have lessened the strength of unions), the organizational strength and demands of environmental groups have remained high or increased several times (Jones and Dunlap 1992).[10] Hence, core countries are both economically enabled and politically compelled to minimize pollution (see also Bunker 1985).

NON-CORE PRODUCTION AND CO_2 FROM FOSSIL FUELS

Among the majority of nations outside of the core, older and/or more polluting forms of production are the norm (Diwan and Shafik 1992, but see Mol and Sonnenfeld 2000). Having a legacy of cheap labor and without the means to build high technology factories, infrastructure, or expensive pollution control devices, many nations have been constrained to use natural resources and labor-intensive production to try to increase their share of global income. These are the countries that we anticipate are producing the greatest amount of CO_2 per unit of GDP in the last decades.

This economic pattern is partly a legacy of the more distant past. Historically, the incorporation of peripheral areas into the emerging world-system typically involved military conquest, the purpose of which was not only for access to natural resources (real or imagined), but also in order to create a stable supply of coerced labor. Later, when these areas won their formal independence from direct European rule, those individuals and firms relying on the production of cheap exports (using coerced labor) for European consumption were usually more deeply established and politically powerful than those who had invested in local manufacturing. Many have described these economies as "disarticulated", as a way to refer to the lack of a connection between local wages and sales of the goods locally produced.[11] By definition, relatively coerced labor, being poorly

9. Most firms and nations are nowhere near those limits, as the work of Hunter and Amory Lovins' Rocky Mountain Institute suggests.

10. This appears to be because these groups cut across class lines, and include large numbers of the growing class of "information workers" (Morrison and Dunlap 1986; Buttel 1992). To some extent, environmental concerns and support for environmental groups has spread through social strata and around the world (e.g. Dunlap et al. 1992).

11. Amin 1976; De Janvry 1981. As suggested above, there are parallels here to the newer literature on social regulation or "post-Fordism."

paid, cannot constitute an important consumer market. It is seen, then, by local capitalists only as means to produce products cheaply, which in their turn are destined for markets in the core.

Over the past 30 years, there has been a substantial growth of industrial capacity in the countries of the semi-periphery and the upper portions of the periphery (Dicken 1998), but these countries continue to be major providers of extractive primary products: fuel, minerals and metals export has remained a substantial part of their exports (World Bank 1992b, 2001).

Regardless of the precise mix of manufactured and primary exports, strategies for upward mobility among the vast majority of countries in the "middle" of the world-system have tended to rely upon a vigorous suppression of production costs and a minimum of government regulation. The poorer infrastructure in most areas outside of the core means that even automated production facilities must often compete against a backdrop of inadequate roads and sometimes intermittent electronic communications. For example, the cost per kilometer of shipping a ton of steel overland in the United States or Japan is likely to be much lower on average than in Brazil, Laos, Guatemala or Cambodia. Isolated countries, most dramatically the small island states, face tremendous transportation costs. Given these infrastructural limitations, the only way that such locations can compete globally in the short term is to make the production process itself as cheap as possible. This almost always includes repressing labor. Hence the disadvantage conferred by poor infrastructure and distance from substantial consumer markets is often compensated for by the cheapness of coerced labor and "fire-sale" prices for natural resources.

In the intensely competitive arena of attracting foreign investors, environmental regulations have often seemed an unnecessary cost driving potential investors away (Roberts 1996a,b; Roberts and Thanos 2003). Further, repressive political climates often vitiate popular initiatives to protect the environment. This has applied regardless of ideological lines—the strategy of production for the world market having been taken up by state socialist nations as well as capitalist economies. The environmental devastation under state socialist regimes in Eastern Europe illustrates what is possible with wider-scale industrialization in semi-peripheral authoritarian states (Kennedy 1993; Manser 1993).

The historical monopoly by the core of the highest technology goods and services has often required that countries outside of the core pay high prices for core products, particularly those designed to improve infrastructure and production facilities (Amin 1976; Frobel, et al. 1980; Vernon 1966).[12] During the 1960s

[12] Some critics see this process continuing today in the export from the core of "green technology" and other high-efficiency equipment (Roberts 1996b; OECD 1994).

and 1970s, these purchases were frequently financed by debt. With skyrocketing interest rates in the 1970s and global recession in the early 1980s, this left many countries caught in a "debt trap," wherein they had to commit a substantial portion of their foreign earnings from exports to servicing debts incurred in their attempts to "modernize." Heavy debt burdens create pressures for "austerity," while increasing the need to generate revenues through yet more export earnings—regardless of long-term environmental consequences and often at the expense of more sustainable approaches.[13]

However, despite these many structural similarities, there is also important and substantial variation within the semi-periphery and periphery. As in the core, such differences are often due to the actions of individual states and the geopolitical circumstances within which they operate, circumstances enabling national ascent within the world-system. For example, some East Asian states were able to avoid the debt traps and resource depletion faced by the countries of Latin America and Africa by receiving exceptionally favorable grants and longer-term loans offered by international agencies, the U.S. government and Japanese lenders (Stallings 1990). These favorable terms were applied to programs of aggressive state leadership and cooperation with export-oriented private firms. Such programs and easy credit combined in the long run to both strengthen these states and reduce the reliance on foreign investment, which elsewhere has frequently led to a drain of wealth through profit repatriation. A few have managed to build world class industrial infrastructure.

East Asia, Latin America and Africa have also varied markedly in their agrarian structures, which has led to more equal distributions of income in Asia and broader internal markets (Kuo, Ranis and Fei 1981; Gereffi and Wyman 1990). The relative lack of natural resources compelled some East Asian states to make the difficult decisions such as land reform and cutting state spending, both made possible by World War Two's outcome (Ranis 1990). This special combination of factors has produced a more efficient export industry generating a higher level of processed goods, and lowered reliance on raw materials exports in countries such as Singapore and South Korea. These two countries' emissions of CO_2/GDP have been among the lowest in the world (WRI 1992, 2002). Nearby Malasia, Indonesia, and Vietnam, however, all of which are reliant on timber exports and are deforesting rapidly, had levels eight to ten times those of Singapore and South Korea in the early 1990s.

[13] E.g. Reed 1992, 1996; but there substantial disagreement on this point.

While industrial processes around the world released about 22 billion metric tons of carbon dioxide in 1989, deforestation in the tropics added another 4 billion tons, accounting for about 16 percent of the total.[14] While releasing carbon, deforestation itself limits the ability of the biosphere to absorb carbon dioxide (Woodwell 1984).[15] Often the same low wages that are characteristic of those countries pursuing the path of producing low cost exports correspond to an inability for the population to afford fossil fuels for cooking, or the equipment and infrastructure that fossil fuel-based cooking requires (see Rudel 1989; Rudel and Roper n.d.). Hence they are compelled to rely upon wood as a primary or even only fuel (WRI 1992).

Below these countries, at the very bottom of the global hierarchy, is the "lower" periphery or "Fourth World," a region documented in some empirical work (Smith and White 1992; Terlouw 1992; Van Rossem 1996). There, minimal technology and abundant labor shapes production into being almost exclusively labor and animal traction intensive, so there is little release of CO_2 from burning fossil fuels. While inefficient in terms of human labor, these methods are considerably more efficient in terms of fossil fules calories consumed. They may, however, still be the sites of heavy use of forest resources for fuel, building materials, or exports.

The overall pattern we expect for fossil fuel emissions of CO_2, therefore, is an inverted U-shaped curve of CO_2 per dollar of gross domestic product (our measure of "CO_2 intensity") when plotted against GDP per capita or other World-System Position measures. The highest polluters per unit of GDP are expected to be in neither the richest nor the poorest countries, but instead those in the middle, roughly corresponding in world-system terms to the semi-periphery and upper periphery. These are the countries having enough fossil-fuel dependent technology to compete in the world market, but not enough sophisticated infrastructure to do so efficiently.[16]

14. WRI 1996: 316, 317; There is substantial debate on the role of land-use change in contributing to carbon emissions.

15. We explore social roots of carbon emissions from deforestation elsewhere (Grimes, Roberts and Manale n.d.). It is critical to acknowledge also the importance of the millions of tons of carbon which were released into the atmosphere over the past three centuries in the United States and other temperate regions when vast portions of the planet's plant cover were removed for agriculture and lumber (Tucker and Richards 1983; Bueno and Marcondes Helene 1991; Neumayer 1999).

16. Such a *pattern* is being predicted and found for a series of environmental variables, including the levels of urban air pollution in the world's megacities (UNEP/WHO 1992; see also Rosa and Krebill-Prather 1993; Grossman and Krugman 1995; Crenshaw and Jenkins 1994; Reed 1992; Roberts and Grimes 1995; Jorgenson 2003). The drop in measured levels of many urban air pollutants in some cities has been attributed to dire calls for pollution controls (UNEP/WHO 1994). Since calls for control of CO_2 have been much more recent and more diffuse, the reversal we find can only be attributed to increased efficiency in production and transportation.

ISSUES OF DATA AND MODEL SPECIFICATION

The estimates of CO_2 emissions from fossil fuel burning activities by country are based largely on energy consumption figures (see Marland and Rotty 1984, and Marland et al. 1989). Specifically, what the Carbon Dioxide Information and Analysis Center (CDIAC) calls "Industrial CO_2" figures are calculated as the sum of emissions from burning solid, liquid, and gas fuels, from gas flaring, and from cement manufacturing (CDIAC 1991). The latter two categories account for only about 3 percent of CO_2 emissions coming from all of these "industrial" sources, so for shorthand we refer to them all as fossil fuel emissions (WRI 1992: 352; see also Stern et al. 1992). It should be pointed out that these fossil fuel figures include both commercial and residential uses. Finally, it should be noted that these data exclude the large contribution of CO_2 from the massive deforestation current throughout the world.

Our cross-sectional research seeks to explore the relations between World-System Position, political repression, and environmental destruction. Included are all nations for which relevant data existed in 1989 and 1998. The data constrain our analysis to pursue only the most basic questions. We obviously cannot capture all of the aspects of the production and consumption conditions that we believe affect CO_2 emissions. Rather, we can only explore here the explanatory power of such variables as are available.

There are no cross-national data available, for example, to directly measure the degree to which labor is coerced, class structures polarized, or consumption patterns channeled towards or away from energy-intensive activities. Even data on wages and income inequality are both scarce and suspect. We are forced to settle for such data as exist, often using proxies for much broader social and political factors. We operationalized some of these *internal* social factors through estimates of inequality, population growth rates, and the size of the government bureaucracy compared to the economy. Political repression was indicated by political and civil freedom (Gastil 1990), percent of the labor force which is organized, and by per capita spending on the military (see Suter and Nollert 1995). External economic relations are measured by world system position, dependence on exports, dependence on narrow range of export products, dependence on a few export partners, by a country's debt service payments divided by its income from export earnings, and the importance of foreign direct investment in the economy (see Walton and Ragin 1990). We summarize our broad theoretical hypotheses and how each was operationalized into specific variables and predictions in the table below. More details on the meaning and measurement (including descriptives and correlations) of the variables are in Appendix A.

SUMMARY TABLE OF HYPOTHESES

Major Conceptual Hypotheses:

H1: National environmental outcomes (in this case carbon intensity) are a result of the nature of that nation's wealth and links to the world economy.
H2: A nation's internal social structure will lead to a high or low "emissions regime."
H3: When infrastructure is poor, political repression is a common means used by peripheral states to keep production costs competitive. Political repression is usually accompanied by less concern or less expression of concern over environmental protection.

Specific Predictions on Direction of Relations with CO2/GDP [predicted direction of relation]:

H1: National environmental outcomes (in this case carbon intensity) are a result of the nature of that nation's links to the world economy.

1.1. CO_2/GDP tends to increase with higher **World System Position (WSP)** or **GDP/capita** because the energy-intensity of economic processes increases (when controlling for the squared term to capture the downward slope—see H1.2). [+]

1.2. Because of improved efficiency in the core, the relation between CO_2/GDP and WSP is an inverted U-curve. Therefore the **square of WSP** will be negatively related to CO_2/GDP, reflecting the down-slope of the curve from the semi-periphery to the core, when controlling for the linear term WSP or GDP/capita. This is true as well for the natural log of GDP per capita and GDP per capita squared.[−]

1.3. Nations with less diverse (more concentrated) exports will have higher CO_2 intensity because those exports tend to be raw and intermediate materials, most of which are energy-intensive to produce. **Concentration of Exports** [+].

1.4. The concentration of countries to which a nation sends its major exports (**Concentration of Export Receiving Countries**) is also expected to be associated with higher carbon intensity, reflecting simple and fragile economies dependent on one trading partner, which is more often the case in post-colonial, disarticulated nations. [+]

1.5. Total intensity of **Exports as a Proportion of GDP** will have mixed association with carbon intensity. This is because substantial exports are now services and light manufactures, rather than the slightly processed metals and agricultural products typical of post-colonial nations. [+/−]

1.6. Nations with heavy debt burdens will need to focus on exploitation of resources and eschew environmental protection to gain hard currencies. **Debt service/exports** [+]

1.7. We expect that levels of **Foreign Direct Investment** might lead to increased carbon intensity, at least if firms are moving out of the U.S., Europe and other more regulated environments to "pollution havens" where they can site the energy intensive portions of the production chain. [+]

H2: A nation's internal social structure will lead to a high or low "emissions regime."

2.1. Countries with disarticulated economies will have high levels of **inequality** (as expressed by the Gini coefficient for income) and high **population growth rates**. Both of these should cause increased carbon intensity by creating desperation and unsustainable practices among marginalized segments [+]

2.2. The allocation of a greater **proportion of the GDP in government spending** may indicate inefficient and sometimes "predatory" rent-seeking state postures towards their economies, and these states may subsidize environmentally damaging (carbon intense) activities, especially in the non-core. [+] Alternatively, in the core, government spending as a proportion of GDP may be associated with tighter environmental regulations and enforcement.

H3: When infrastructure is poor, political repression is a common means used by peripheral states to keep production costs competitive. Political repression is usually accompanied by less concern or less expression of concern over environmental protection.

3.1. Political repression will disable or preempt pressure from local or international environmental organizations which might improve carbon intensities. **Regime repressiveness** is indicated by Gastil's index of political and civil rights [+]

3.2. Greater proportions of laborers in unions may indicate greater civic participation and political space for environmentalists. **Percent of Labor Organized** [−]

3.3. In many non-core nations, military spending supports internal political repression. In both core and non-core nations, military spending often involves direct polluting and often economically non-productive activities. **Military Spending/GDP** [+] We have similar predictions for **military personnel per thousand population**. [+]

To test for the inverted U-shaped curve we predicted, we included in our regression equations both the natural log of World-System Position (for the upward trend) and a quadratic term (for the downward slope) (following Berry and Feldman 1985: 57–60). The remaining predictors in the equation were designed to assess with the data available how well the other social factors discussed earlier can explain the deviations away from these major trend lines. To evaluate some of the direct effects of world market forces, we used the concentration of export commodities as a proxy for trade specialization, and the ratio of debt service payments over the earnings from all exports to reflect the pressure of external debts. To test whether state strength played a role in production efficiency, government consumption as a percent of GDP was included. We used three indicators for political repression: regime repressiveness, percent of labor organized, and military spending per unit of GDP.

A series of other methodological problems remain, several of them unresolvable given the data available. First, many variables were highly skewed and so were logarithmically transformed by standardized criteria.[17] Ratio variables were required in several cases to correct for the size of the population or GDP in a nation (see Firebaugh and Gibbs 1985). Multicollinearity is a concern, especially for variables tied to national wealth, and so we have attempted to examine their effects in separate and combined equations.

Fourth and most troubling is that much important data are missing in a non-random fashion. Usually, data are least available for countries in the periphery, introducing a sampling bias favoring wealthier countries. While some small states are present in the sample, evaluation of outliers indicated they do not profoundly skew the distributions. Rather, the most complete data sets are from the core and semi-periphery; the World Bank or United Nations are often entirely missing data for both the smallest micro-states and many previously or currently communist states (Bollen, Entwisle and Alderson 1993; Grimes 1996). However one indicator central to our argument (debt service as a percent of export earnings) posed the opposite problem: data were missing for the core. Unfortunately, several other variables were dropped from the analysis because of difficulties in validity and availability of data; level of technology and international competitiveness (see Fajnzylber 1990b); natural resources endowment (see Ranis 1990); business leadership, sectoral disarticulation, poverty, and so on.[18]

Because of larger amounts of missing data in the periphery, list-wise deletion of missing data would have further skewed these samples or made regressions impossible. Rather than impute values for countries without data based on similar ones, we reluctantly use pair-wise deletion of missing cases as the lesser of two evils. A result of this procedure is that even countries without data for one

17. We logged those variables whose skews were greater than 1.0, and kurtoses were greater than 1.4.

18. OECD data on poverty from the Luxembourg Income Project (Buhmann, Rainwater, Schmaus and Smeeding 1987) are highly incomplete and not readily comparable. The same is true of World Bank data (2001).

variable are used to model the relations between other variables for which we do have data. We attempt to check for "instability" in the regression coefficients as samples shift with different model specification.

Because of these sample biases and methodological quandaries, the use of statistical tests in what follows must be treated with caution. It should be pointed out that our goal is only to discover the *direction* of overall relation, not their absolute magnitude. For this reason in Table 1 we report both unstandardized b's and standardized beta values, since the metric b's are not additive and not readily interpretable after some variables were ratioed and logged. We also have reported a rather large number of models, which examine the impact of variables on sample sizes and allow comparison of measures. If nothing else, the table shows how the insights which come from many social variables unfortunately come with significant costs in terms of statistical robustness.

CO_2 INTENSITY AND GLOBAL STRATIFICATION

Figure 1a shows the distribution of CO_2/GDP across nations of increasing levels of national wealth (GDP per capita), and Figure 1b shows how carbon intensity varies across levels of GDP per capita and World System Position. Both are apparently curvilinear relationships with substantial scatter. Because of the scatter the shape resembles a turtle more than an inverted u-curve. Interestingly, WSP seems to better capture the upward slope on the left of the graph, while GDP per capita has a fairly clear downslope among the wealthiest countries (above 8.5 in ln GDP/capita). Countries on the left and right ends (the extreme periphery and core, respectively) cluster near or below 5 in lnCO_2/GDP (about 1.65 tons per million dollars), while nations whose logged WSP index score lies between −4 and 3 produce more CO_2 per unit of GDP.[19] It is noteworthy that across the full range of WSP values there are nations producing less CO_2 per GDP, but most of these lie in the extremes, particularly in the core and upper periphery. This upside down "U" curve (or more precisely, the turtle shape) is consistent with our theoretical expectations (see also Roberts and Grimes 1997).

19. The line between core and non-core is by necessity somewhat arbitrary. Using graphical presentation of World-System Position scores by country rank we looked for break points near the line where consensus broke down between the eight classical study authors tabulated in Terlouw (1992: Appendix 3A). For the purpose of this study, we decided that non-core countries were those with our index scores for WSP below 32 of the possible 100. In the graphs above, this value corresponds to a log value for WSP of 3.47.

Figure 1 – Carbon Dioxide Emissions in the World System

Figure 1a: Natural log of national carbon emissions intensity (CO_2 emissions per unit of GDP), versus GDP per capita, 1998.

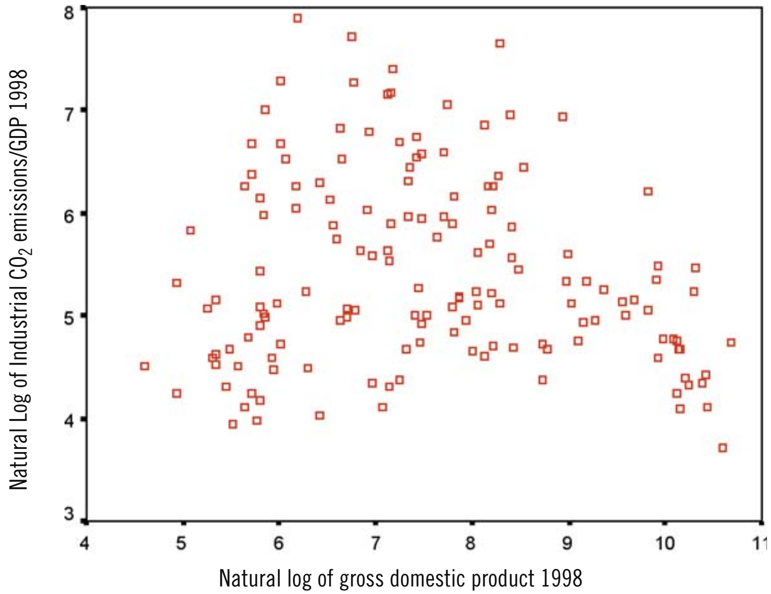
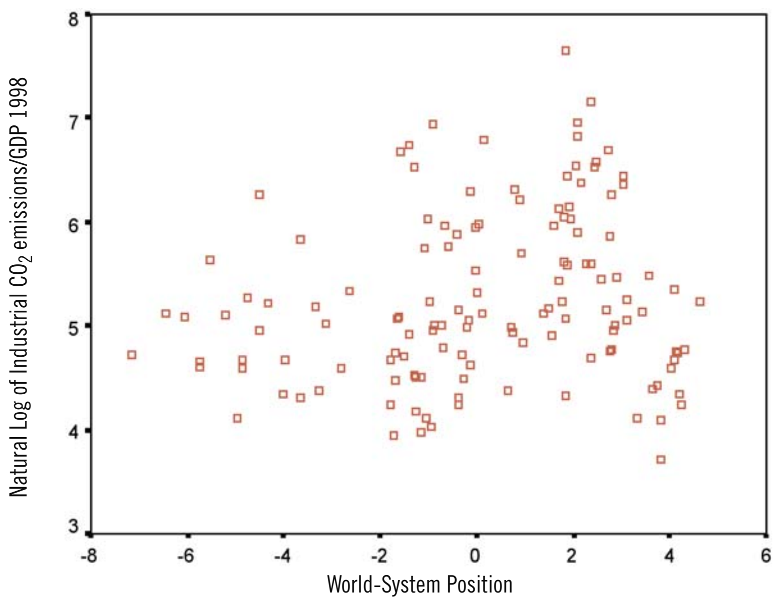


Figure 1b: Natural log of national carbon emissions intensity (CO_2 emissions per unit of GDP), 1988, vs. hybrid Terlouw index of position in the world system.



These figures show that no thermodynamically fixed relation between world system position and actual CO_2 emissions exists. Some thermodynamic minimum doubtless exists (Georgescu-Roegen 1971; Commoner 1977—unless non-carbon sources become ubiquitous), but this minimum is surpassed by many nations in a way that appears to be socially determined and often independent of position in the world stratification system (see also Goldemberg, Johansson, Reddy, and Williams 1985). What is more, there is huge variation in the upper periphery and semi-periphery, and many of the theoretical arguments gleaned and developed from world-systems theory above suggest why that might be. Our final task here then is to identify the social pressures that push these countries to consume fuels in quantities much greater than the levels of other similarly positioned countries. Below we test the tool of multiple regression in providing initial insights into identifying which forces might create that push. We compare 1989 results (Table 1) with models for 1998 (Table 2), the most recent available in early 2003. The two analyses are similar, but reflect our evolving thinking about these issues over the past decade and work on two separate datasets for the two years. With the exception of GNP/Capita, the predictors for the 1998 CO_2 data were all drawn from the same data as the 1989 data, so in that sense the 1998 analysis may be thought of as lagged.

MODELING SOCIAL FACTORS

Most striking amongst results from Tables 1 and 2 is that in both 1989 and 1998 the internal/social indicators are more powerful in predicting CO_2 intensity than were variables indicating links to the world economy (exclusive of WSP). However a number of these significant relations were in the opposite direction from the predictions we laid out in the text and summary table above, suggesting some revisions in our theoretical frame. We begin by interpreting these social factors.

To begin interpreting these findings, we can point out that GDP and WSP are important predictors of carbon intensity. World-System Position and GNP/capita were strongly predictive of carbon intensity in both years. All four were in the predicted directions: the logged terms were positively related to carbon intensity, representing the upward slope of the inverted U-curve discussed above, while the squared terms were negative, capturing the downward slope of CO_2/GDP in the core, seen in figures 1a and 1b and as we predicted. WSP more effectively captured the upward linear side of the relationship in 1998, but GNP/capita best captured the downward side. So we used WSP and GDP/Cap^2 in further models. In an analysis of subgroups for the 1989 sample we found that these variables were not significantly related to carbon intensity when core nations were removed (results not shown). What this means is that overall, wealthier, more powerful countries are more intense in carbon emissions per unit of GDP, but that the countries at the very top of the wealth hierarchy have become more energy efficient, and therefore less carbon intense (see Roberts and Grimes 1995).

However the most effective partial models from the 1989 analysis are those for H3, indicating the importance of repression in influencing national CO_2 intensity. This is also true in the full models: holding WSP, its square, and the other variables in the full models constant, the size of military spending relative to the size of the economy (GDP) was among the strongest predictors of CO_2/GDP. Put another way, within any given value of WSP, states spending more on the military are also states producing significantly more CO_2 from fossil fuel sources per unit of GDP compared with states spending less. This remained true in three of four models in the 1998 analysis. This is consistent with our expectation that ***militarized states suppress labor costs to make up for inefficient infrastructure***. Also, the military can **itself** be an important polluter, insofar as they use equipment and vehicles that are extremely inefficient from an energetic point of view (Kennedy 1987; Suter and Nollert 1993). Some core nations have used military spending as a Keynesian tool to avoid the "underconsumption crisis" of capital surpluses and threats of economic stagnation. Still, studies of the "multiplier effects" of military spending have found it to be extremely inefficient economically. Finally, it may also be the case that countries committed to high military spending are also countries with many "inefficient" industries (Fajnzylber 1990b).

While each of these hypotheses are consistent with the data, the first interpretation is also supported by the strong negative effect of the percent of labor organized, and the positive influence of Gastil's index of regime repressiveness on CO_2 inefficiency (significant only in the 1989 analysis). An analysis of 1989 data (results not shown) revealed that the predictive power of regime repressiveness becomes stronger, as does that of the percent of labor organized, when we look at only non-core countries. Another OLS analysis, this one of 1998 data which included only three terms (regime repressiveness, GDP/capita and its squared term) showed a strong positive relationship between repressiveness and carbon intensity (results not shown). These increases in magnitude indicate that our theory of repression as a compensation for inefficient infrastructure appears to have the greatest salience for countries outside of the core.[20] Consistently nega-

[20]. In analysis not shown, we find that contrary to our expectation and much of the recent literature tying poverty to pollution, countries for whom we have data with higher

Table 1: Unstandardized and (Standardized) Regression Coefficients for Natural Log of Total Carbon Dioxide Emissions from Industrial Sources (mostly fossil fuel consumption) per unit of Gross Domestic Product, 1989.

	Model 1 1989		Model 2 1989		Model 3 1989		Model 4 1989		Model 5 1989	
VARIABLE	***b***	**Beta**	***b***	**Beta**	***b***	**Beta**	***b***	**Beta**	***b***	**Beta**
Ln(GDP/cap)	.177**	.298	.390***	.658						
(GDP/cap)^2	.000***	–.567	–.000*	–.387						
Ln(WSP)	144***	.448			.132*	.411	.114**	.355	.134***	.415
(WSP)^2	–.000	–.092			.000***	–.438	–.000***	–.409	–.000*	–.213
GDP growth			–.027	–.083	–.039	–.199				
Ln(Conc.Exports)			.042	.038	.300	.268				
Ln (Debt)			.081	.070	.058	.050				
Population Growth			–.157	–.221	.311**	.439	–.202*	–.285		
Gcon/GDP			–.462	–.407	–1.92	–.169				
Military Spd/GDP			+++	+++	.289***	.582	.249***	.501		
Repressiveness			.084*	.397	.062*	.292	.065*	.306	.042*	.201
%Labor Organized			–.014*	–.359	.024***	–.634	–.021***	–.557		
Adjusted R^2		**.249**		**.183**		**.407**		**.373**		**.162**
Min. pairwise *N*		***154***		***65***		***65***		***77***		***154***

Note: * $p<.05$; ** $p<.01$; *** $p<.001$
+++ Military spending/GDP was too highly intercorrelated with GDP/capita to include both in the full model

Table 2: Unstandardized and (Standardized) Regression Coefficients for Natural Log of Total Carbon Dioxide Emissions from Industrial Sources (mostly fossil fuel consumption) per unit of Gross Domestic Product, 1998.

VARIABLE	Model 1 1998		Model 2 1998		Model 3 1998		Model 4 1998		Model 5 1998		Model 6 1998	
	b	Beta	*b*	Beta	*b*	Beta	*b*	Beta	*b*	Beta	*b*	Beta
Ln(GDP/cap)	.015	.025					−.016	−.026				
(GDP/cap)^2	−.000***	−.503					−.000***	−.446	−.000 ***	−.475	−.000 ***	−.488
Ln(WSP)	.149***	.438					.182***	.537	.148 **	.437	.177 ***	.522
(WSP)^2	−.000	−.071					−.000	−.049				
Ln (Exports/GDP)			.198	.149			.373*	.282	.324*	.245	.372 **	.281
Ln (Conc. Exports)			.163	.139								
Ln (Conc.Exp Rec'g Countries)			.367*	.238					.281+	.183		
Ln (Debt)			4.210***	.380					2.540*	.229		
FDI/GDP			−.036	−.062								
Military Spd/GDP					4.354	.206	5.479**	.260	6.191 **	.293	5.500**	.261
Military Person /Pop					.200	.205						
Gini Inequality					−.004	−.051						
Repressiveness					.014	.063						
%Labor Organized					−.014*	−.338	−.016**	−.387	−.012 **	−.293	−.016***	−.385
Adjusted R^2	**.248**		**.179**		**.229**		**.490**		**.536**		**.488**	
Min. pairwise *N*	***132***		***80***		***59***		***77***		***65***		***77***	

Note: +p <.10; * p<.05; ** p<.01; *** p<.001

tively related to carbon intensity in both years was the percent of labor organized in unions. The variable has a series of problems, but its consistent relationship with carbon intensity suggests that it requires further examination in the future.

Interestingly and contrary to prediction, in the models of the 1989 analysis the role of population growth is strongly negative, indicating at the same time that CO_2 output is *not* merely a by-product of demographic pressure, and that countries experiencing high population growth rates are not necessarily the countries with the least efficient fossil fuel consumption. Though the source of substantial debate, population has been argued to be much less predictive of total environmental impact than is affluence or the technological level of a society (Commoner 1977; Dietz and Rosa n.d.). Also, countries experiencing the highest rates of population growth are also largely agrarian, hence less involved in industrial production (Grimes, 1982). The Gini index of income inequality, which we added for the 1998 analysis, was not significantly related to carbon intensity.

The relative size of the state, as measured by government consumption per unit of GDP, also had a negative influence on CO_2/GDP in 1989, but was never statistically significant. Further analysis of partial correlation coefficients (holding WSP constant) reveals that, in the lower periphery, a highly consumptive state accompanies higher CO_2 generation from fossil fuel sources, but in the upper periphery & semi-periphery the relationship reverses, with "strong" states being the most "efficient", generating the least CO_2 per unit GDP (results not shown). This may mean that among the poorest countries, the state is the major consumer of fossil fuels, but among the more powerful countries in the upper periphery, semi-periphery, and core, stronger states—net of political repression—may have instituted tighter environmental regulations and/or built higher quality infrastructure. Finally government spending, excepting militaries and relatively rare cases of state-owned steel mills and mines, is almost exclu-

proportions of their populations living below their poverty line tend to emit *less* fossil fuel CO_2 per unit of GDP. The zero-order correlation of carbon intensity and poverty rates is strongly negative (r=−.425). As Barkin (1995) and others have pointed out, the rich and poor create radically different types of pollution. Consumptive behaviors requiring the burning of fossil fuels are often seen as a hallmark of affluence and status. It appears that this finding can also be partially attributed to the positive correlation between political repression and poverty. That is, once the (significant first-order) positive association between repression and poverty is accounted for, the residual effect of poverty is to reflect societies where there is less money for burning fossil fuels. Second, definitions of poverty and therefore national poverty rate indices vary tremendously by country and WSP (see ILO 1993).

sively in the service sector, and therefore less energy-intense than industries.[21] To summarize these two points, overall state spending (govt/GDP) appears to lessen CO_2 per unit GDP, while military spending tends to increase it strongly. These two variables were in fact not measuring the same thing: their zero-order correlation was r = .0401.

Globalization, or the strength of a nation's links to the world economy and its major institutions, was measured in several ways which proved to be variously predictive of carbon intensity. Total exports as a percent of a nation's GDP (which might be called "export dependence") was positively related to carbon intensity in 1998 when we added it to the models. Export concentration (the limitation of a country to a few major export products) was mildly related to carbon intensity. In further analysis of the 1989 results, this was especially true in non-core states, and the relation was revealed only when internal social variables just discussed were held constant (results not shown). This finding indicates that dependence upon a narrow range of export commodities to earn foreign exchange is a pressure that may be compelling certain countries to produce without regard to environmental cost. The 1998 analysis shows that being dependent on few export *partners* was bad for carbon intensity, supporting the "colonial legacy" argument made above. Finally, and contrary to prediction, overall foreign direct investment was not related to carbon intensity.

Though many authors have tied debt to ecological destruction (e.g. Reed 1992, 1996; Schwartzman 1986; Roberts and Brook 1998), we found somewhat nuanced results. A five-year average of a nation's foreign debt as a percent of its export earnings (1983–1987) was only weakly positively related to national carbon intensity from fossil fuels in 1989, but was more strongly related to carbon intensity in 1998. This suggests a possible *lagged* effect of debt on carbon inefficiency (the pressure to step up exports in order to meet debt service payments) which bears further investigation.

Meanwhile our indicator of economic growth (GDP growth rate between 1980 and 1989) was seen to have a moderately *negative* association with carbon intensity (contrary to our prediction). This suggests that the fastest growing economies throughout the eighties were those investing in industries that generate relatively lower levels of CO_2 per unit of economic activity generated. Examples of such investments might be tourism, banking and light assembly,

[21] Schnaiberg (1980), however, makes the important point that restructuring towards a service economy does not mean the end of material consumption on a devastating scale.

with slower growth in countries dominated by older heavy industries (e.g. Eastern Europe, the core).[22] Said the other way around then, these findings suggest that countries which are reducing their CO_2 intensity appear to be also those which experienced the strongest economic growth in the 1980s. We found in a similar analysis that there is a connection between national debt and carbon emissions intensity from deforestation (Grimes, Roberts and Manale, n.d.). The important question of patterns in rates of *change* in carbon intensity must await future research.[23]

SUMMARY AND CONCLUSION

This study set out with three goals. First, we sought to open a new area of theory connecting economic, social and political factors with levels of national carbon dioxide emissions. Second, we wished to examine how the global hierarchy of nations affects the broad pattern of emissions of CO_2 per unit of GDP. Third, we hoped to explore the ability of local social indicators to account for the variance among national levels of CO_2/GDP between countries occupying similar World-System Positions. While the results are somewhat mixed, the cross-sectional portion of this analysis has confirmed the importance of a country's role in the world economy and the internal strength and repressiveness of its state in explaining its levels of CO_2 emissions per unit of GDP. While most previous studies on energy use, deforestation and greenhouse emissions have limited themselves to more proximate causes, our analysis has shown that when considered together, measures of the deeper social fabric can account for some of the variability in countries better than do more proximate ones.

Our central theoretical expectation was that countries lacking a modern infrastructure and a strong internal market are forced to produce for the world market with low-cost raw materials and low-wage, coerced labor, using capital fleeing the high wages of the core. We anticipated that many of these would also be states which have welcomed "dirty" industries fleeing growing environmental regulation in the core. Since these conditions are often found in the countries of

[22] On whether GDP growth and debt are intertwined, we would expect that countries growing more quickly should be more able to service their external debts, but GDP growth and Debt were only slightly negatively correlated here (see Appendix A). And statistically, of course, growth of GDP increases the denominator in our intensity measure.

[23] Andersen 2002 makes interesting use of a new measure of rates of change of carbon emissions and economic growth, as a measure of "ecological modernization" in Eastern European nations.

the upper periphery and semiperiphery, we looked for the least efficient producers there. Further, the de-industrialization of the core via capital flight would have the effect of apparently "improving" the CO_2 efficiency of capital accumulation in the core.

In general terms, these expectations were borne out in the descriptive and regression analyses, but the OLS regressions revealed some surprising findings. When countries were ranked by their world system position, an imperfect upside-down "U" curve of the tons of CO_2 emitted per million dollars of GDP output became evident (Fig. 1). While these figures show the value of the WSP term in capturing the linear upward relationship with CO_2/GDP, and GNP/capita in explaining the downward curve, equally evident is the tremendous variation around this upside-down U-curve (making it more closely resemble a "turtle"). This "Environmental Kuznets Curve" has been observed and predicted elsewhere (e.g. Reed 1992: 146; UNEP/WHO 1992; Grossman and Kreuger 1995; Roberts and Grimes 1997; and a series of articles in *Ecological Economics*). However, to find this inverted U-curve in a gas until recently not considered a "pollutant" (CO_2) indicates that sometimes economic and infrastructural factors combine to reduce emissions without there being explicit pollution control measures (Mol 2001). We return to this important point shortly.

Second, most discussions of the relationship between pollution or energy use and "level of development" have either discussed the linear pattern or the scatter around the line, without explaining what influences might be operating to create the "scatter". Herein lies a critical policy implication of this research: that countries in some economic situations are far more likely to be high CO_2 emitters than are others. Our multivariate analyses show that by including measures of WSP and other variables reflecting global social structure and national economic strategies, we can substantially improve our understanding of environmental problems such as global warming.

Variations in levels of emissions from fossil fuel sources were best explained by a nation's debt, total exports and military spending, population growth rate, the percent of labor organized, and the repressiveness of their political regime. We believe the bigger picture is that to be competitive in the increasingly global economy, production for both home and world markets must often compensate for poor infrastructure and energetically inefficient production techniques by suppressing labor costs and raw material prices (see McMichael 1996). This suppression of labor requires the existence of an oppressive state apparatus, reflected by a strong military, weak, co-opted, or non-existent unions, and a repressive political environment, as indicated by civil and political rights. These social systems, of course, are often fragile politically.

In the field of development studies, a core debate is between authors claiming nations control their own destiny and those who point to how the global economy provides few avenues for upward mobility and traps nations in unfavorable relationships (Roberts and Hite 2000). It is not necessary here to repeat the arguments of the modernizationists on the one hand—those pointing to internal and cultural barriers to development—and the dependency/world-system theorists on the other. The appearance of an inverted U-curve indicates that a country's structural location within the global economy imposes some constraints on its organization of production, constraints which in their turn tend to lead to CO_2 production per unit of GDP output within a certain range. However in this case these constraints are clearly not rigidly deterministic because within every category of world system position there is considerable variance.

In our multivariate models, however, we have evaluated the power of partial models divided by internal and external factors in predicting national carbon intensity (Tables 1 and 2). Our approach reflects our belief that this dichotomy is largely false: ***a nation's internal class and political structures are largely but not entirely the result of their links to the world economy***—their amount and variety of exports and trade partners, levels and types of debt, and most generally their position in the world economy (see e.g. Karl 1997). Some causal influence obviously runs in the opposite direction, as local actors respond to the constraints and opportunities of the evolving world system.

The findings presented here are most convincing that repression plays an important role in national "pollution regimes," making up for poor infrastructure and distance to consumer markets. Therefore of our third major conceptual hypotheses, H3, which asserted that repression was accompanied by less expression of concern over environmental protection, was the most convincingly supported. Our first hypothesis, H1, held that environmental outcomes of nations are directly a product of their position in the world economy is also supported. Fossil fuel carbon intensity was related to a nation's WSP and its square, weakly positively linked to the narrowness of a nation's export portfolio, and debt levels, but only in the 1998 models.

These findings have critical implications for the likely future of global warming. Most of the production of CO_2 comes from the United States and Europe, and besides booming emissions in China and India, this will probably be true for the foreseeable future. But progressive technological improvements, government regulations, and conservation-oriented programs have a chance to continue to reduce the production of CO_2 per unit of GDP in the core. Switching fuels and putting carbon-scrubbers on power plants and factories can be extremely expensive (see e.g. Cheng, Steinberg and Beller 1986; Steinberg, Cheng and Horn 1984), and it may be that given the legitimation needs of the system for growth, even considering reducing CO_2 by planned reductions in the GDP would probably be political suicide (see Schnaiberg 1980; O'Connor 1973). Still, surveys in both core and peripheral nations have shown at least verbal support for stronger protection of the environment, even at the expense of economic growth (Dunlap et al. 1992; Inglehart 1995).

Meanwhile, the relative carbon intensity of the semi-periphery is likely to persist or even grow, and, to the extent that they succeed in capturing a larger portion of the global market, their collective contribution to global warming will almost certainly increase. This can only result in increasing global CO_2 emissions, unless the increase in efficiency in the core can offset the explosive growth in CO_2 production likely in the semi-periphery & upper periphery, again, especially in China and India (WRI 1996). Reaching the 1992 U.N. Framework Convention on Climate Change and the Kyoto Treaty's goal of stabilizing CO_2 emissions at 1990 levels will probably require some combination of these. If the inverted U-curve is any indication, reducing CO_2/GDP should be far easier for wealthier countries already on the downward side of the U. Because of structural constraints on nations and their internal problems, we do not believe most nations will ever reach a "turning point" where pollution begins to lessen due to improving efficiency (see Grossman and Kreuger 1995; Roberts and Grimes 1997). The problem needs to be addressed explicitly, because economic development alone will not necessarily lead to greater efficiency and reduced emissions.

The most probable outcome will be continued warming, the results of which we leave to other researchers in the area. To avoid this outcome, our research suggests that it will be necessary to improve the quality and energetic efficiency of the infrastructure of production, distribution, and consumption in the core, but also in the semi-periphery and periphery. Such improvements should be complimented by serious efforts by all countries to shift away from fossil fuels, and they could only be made quickly if efficient technologies and infrastructures were distributed in a subsidized way to the non-core in a concerted, systematic fashion. Specifically, this research suggests a globally-directed and largely core-funded effort at improving roads and equipment, increasing use of non-fossil fuel energy sources, conservation, and recycling. Such efforts should be targeted especially in the semi-periphery. Unfortunately, insofar as such investments are vitiated from the start by the structure of the world-economy, improvements along these lines would most likely emerge as a result of a sharp increase in the price of oil rather than international cooperation. Perhaps the most important finding of this research, however, is that national levels of carbon dioxide intensity are tied to many deep internal and external structural conditions in societies and that these factors vary by position in the world stratification system. The implications of this are clear: that attempts to reduce CO_2/GDP in the future will require far more profound changes in societies than merely introducing new technologies.

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APPENDIX A: DEFINITIONS, SOURCES OF DATA, DESCRIPTIVE STATISTICS, AND CORRELATIONS

LN(Industrial CO_2 emissions/GDP) [$LNICO_2GD$]: Natural log of metric tons of CO_2 emissions from fossil fuel use, cement manufacture, and gas flaring, per unit of GDP, 1989 (CO_2: CDIAC 1991; Marland and Rotty 1984; GDP: World Bank 1992c; WRI 1992).

LN(Total CO_2 emissions/GDP)[$LNCO_2GDP$]: Natural log of sum of Industrial and Deforestation CO_2 emssions/GDP. See above for sources.

LN (GDP/*Capita*) [LNGDPCAP]: Natural Log of Gross Domestic Product 1989 (World Bank).

LN (GNP/*Capita*) [LNGNPCAP]: Natural Log of Gross National Product 1998 (World Bank).

LN (World-System Position); (World-System Position) Squared [LNWSP, WSP2]: Average of Terlouw's "second-order regionalization" of the world system and a country's trade as a percent of world trade. The former scores were derived by Terlouw from applying a form of factor analysis that manipulates nominal-level data to the World-System Position assignments of individual countries provided by 5 major theorists in 8 works or time periods (Terlouw 1992: Appendix 3A). We converted these factor scores into index scores varying between 0 and 100. We also converted the percentage of world trade accounted for by each country into index scores (also from Terlouw 1992). These two indices, each varying from 0 to 100, were averaged to generate our WSP score. When no data were available for one or the other, the available index was substituted.

LN(Military Spending/GDP) [LNMILSPD]: Natural log of military spending as percent of nation's gross domestic product (World Bank 1992c).

Military Personnel/000 Population [MILLPOP]: Taylor and Jodice, 1983.

Pop. Growth Rate [POPGRO89]: Average annual growth of population (percent) 1980-1989 (World Bank 1991; 1992a)

% Labor Organized [ORGLAB75]: Organized Labor as a Percentage of Total Labor Force, c. 1975. (Taylor and Jodice 1983). These data refer to the percentage of employed and unemployed persons that belong to the organized trade unions, whether independent or not.

Regime Repressiveness [REPRESS]: Sum of annual ratings on two seven-point scales of civil and political rights, 1989 (Gastil 1990; Boswell and Dixon 1990).

LN(Exports/GDP) [LNEXGDP]: Exports in 1989 (World Bank) divided by GDP 1989.

LN(Conc. of Exports) [LNCONEXP]: Concentration of Export Commodities, 1975. (Taylor and Jodice 1983). Concentration is higher the fewer the export divisions (SITC codes) and the greater the value of the largest divisions.

LN(Conc. of Export Receiving Countries) [LNCNEXR]: (Taylor and Jodice 1983).

FDIGDP (Foreign Direct Investment/GDP): Average of net foreign direct investment as reported by the World Bank 1982-1987 divided bt GDP 1989.

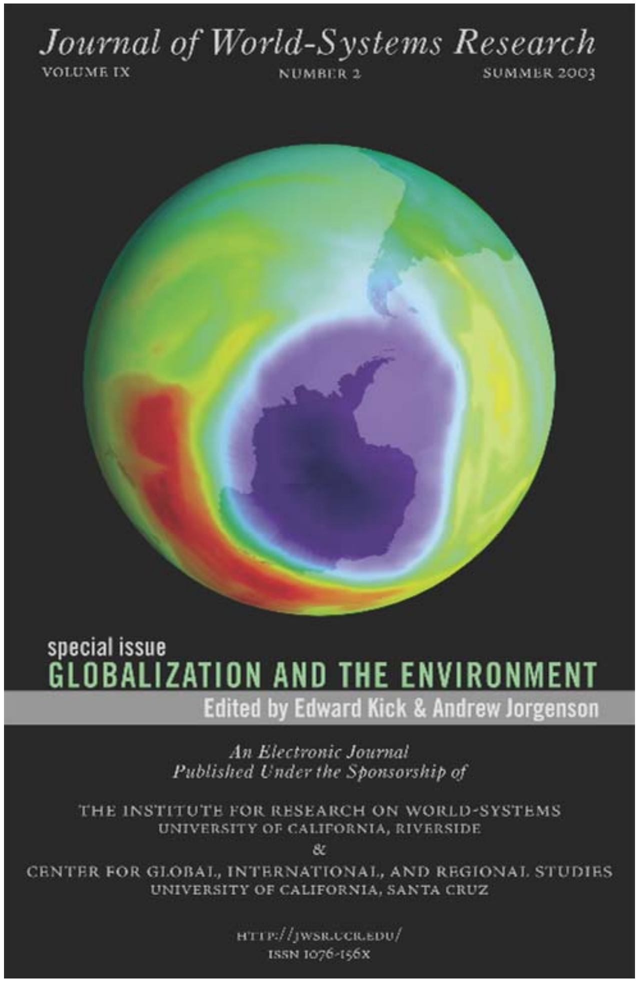
Gov't Consumption [GCON8089]: Government spending as a percent of current GDP, 1980-1989 (World Bank 1992c).

LN(debt service/exports) [LNDEBT]: Natural log of five year average of total debt service /total export earnings, 1983–1987, in millions of U.S. $ (World Bank 1992c; WRI 1992).

DESCRIPTIVE STATISTICS FOR 1998 ANALYSIS

	N	Minimum	Maximum	Mean	Std. Deviation
LN KILOS CO2/BIL GDP $US	133	10.66	14.30	12.3252	.7722
LNCOGD98	151	3.71	7.91	5.4195	.9274
LNGDCP98	157	4.61	10.68	7.4994	1.5449
GNP/CAP '98 SQUARED	157	10000.00	1898344900.00	116322390.6051	299800679.9105
LNWSPETE	162	–7	5	.15	2.74
WSPETESQ	162	.00	10000.00	439.2131	1347.9999
LNEXPGDP	132	1	5	2.92	.70
LNCONEXP	119	4	7	5.45	.79
LNCNXREC	120	4	7	5.07	.60
LNDEBT	104	–5	–1	–2.03	.76
LNFDIGD1	106	–7	2	–0.94	1.59
Military Spending/GDP 87	99	–35.31	.00	–1.6421	4.4140
MILMAN75	135	0	934	124.60	136.78
GINI	94	2	63	38.92	11.43
FREE1988	163	2	14	8.28	4.18
RORGLAB75	100	0	100	26.14	23.03
Valid N (listwise)	30				

		LN KILOS CO2/ BIL GDP $US	LNCOGD98	LNGDCP98	GNP/CAP '98SQUARED	LNWSPETE	WSPETESQ	LNEXPGDP	LNCONEXP	LNCNXREC	LNDEBT	LNFDIGD1	Military Spending/ GDP 87	MILMAN75	GINI	FREE1988	RORGLAB75
LN KILOS CO2/BIL GDP $US	*R*	**1**	**0.818**	**0.11**	**-0.21**	**0.273**	**-0.08**	**0.199**	**-0.03**	**-0.05**	**0.152**	**0.063**	**0.172**	**0.302**	**-0.08**	**0.092**	**-0.15**
	Sig.	.	0	0.236	0.026	0.002	0.344	0.029	0.773	0.615	0.154	0.537	0.088	0.001	0.518	0.296	0.155
	N	133	117	118	118	129	129	120	105	105	89	99	99	112	75	130	88
LNCOGD98	*R*	**0.818**	**1**	**-0.14**	**-0.32**	**0.175**	**-0.18**	**0.15**	**0.127**	**0.148**	**0.272**	**0.027**	**-0**	**0.244**	**-0.04**	**0.206**	**-0.31**
	Sig.	0	.	0.082	0	0.045	0.036	0.11	0.212	0.142	0.01	0.796	0.973	0.01	0.742	0.018	0.004
	N	117	151	150	150	132	132	114	99	100	90	95	92	112	90	132	85
LNGDCP98	*R*	**0.11**	**-0.14**	**1**	**0.67**	**0.473**	**0.527**	**0.411**	**-0.51**	**-0.23**	**0.016**	**0.118**	**0.207**	**0.267**	**-0.38**	**-0.7**	**0.444**
	Sig.	0.236	0.082	.	0	0	0	0	0	0.024	0.882	0.253	0.048	0.004	0	0	0
	N	118	150	157	157	134	134	116	100	101	91	96	92	114	91	134	87
GNP/CAP '98 SQUARED	*R*	**-0.21**	**-0.32**	**0.67**	**1**	**0.481**	**0.651**	**0.19**	**-0.39**	**-0.22**	**0.008**	**-0.11**	**0.171**	**0.022**	**-0.35**	**-0.48**	**0.364**
	Sig.	0.026	0	0	.	0	0	0.041	0	0.028	0.938	0.292	0.102	0.82	0.001	0	0.001
	N	118	150	157	157	134	134	116	100	101	91	96	92	114	91	134	87
LNWSPETE	*R*	**0.273**	**0.175**	**0.473**	**0.481**	**1**	**0.463**	**0.073**	**-0.41**	**-0.29**	**0.475**	**-0.37**	**0.399**	**0.283**	**-0.44**	**-0.19**	**0.359**
	Sig.	0.002	0.045	0	0	.	0	0.408	0	0.001	0	0	0	0.001	0	0.013	0
	N	129	132	134	134	162	162	131	119	120	104	106	99	135	80	162	100
WSPETESQ	*R*	**-0.08**	**-0.18**	**0.527**	**0.651**	**0.463**	**1**	**-0.03**	**-0.37**	**-0.24**	**0.145**	**-0.21**	**0.137**	**0.005**	**-0.23**	**-0.4**	**0.167**
	Sig.	0.344	0.036	0	0	0	.	0.766	0	0.009	0.143	0.028	0.177	0.954	0.042	0	0.096
	N	129	132	134	134	162	162	131	119	120	104	106	99	135	80	162	100
LNEXPGDP	*R*	**0.199**	**0.15**	**0.411**	**0.19**	**0.073**	**-0.03**	**1**	**0.126**	**0.126**	**-0.08**	**0.454**	**0.027**	**0.09**	**-0.19**	**-0.25**	**0.268**
	Sig.	0.029	0.11	0	0.041	0.408	0.766	.	0.204	0.202	0.424	0	0.8	0.348	0.116	0.004	0.011
	N	120	114	116	116	131	131	132	103	104	94	102	94	112	72	132	90
LNCONEXP	*R*	**-0.03**	**0.127**	**-0.51**	**-0.39**	**-0.41**	**-0.37**	**0.126**	**1**	**0.212**	**-0.19**	**0.175**	**-0.21**	**-0.09**	**0.266**	**0.413**	**-0.12**
	Sig.	0.773	0.212	0	0	0	0	0.204	.	0.022	0.086	0.11	0.049	0.339	0.024	0	0.282
	N	105	99	100	100	119	119	103	119	117	80	85	89	118	72	119	90
LNCNXREC	*R*	**-0.05**	**0.148**	**-0.23**	**-0.22**	**-0.29**	**-0.24**	**0.126**	**0.212**	**1**	**-0.31**	**0.208**	**-0.35**	**-0.21**	**0.309**	**-0**	**-0.17**
	Sig.	0.615	0.142	0.024	0.028	0.001	0.009	0.202	0.022	.	0.005	0.058	0.001	0.024	0.008	0.982	0.103
	N	105	100	101	101	120	120	104	117	120	82	84	90	119	73	120	90
LNDEBT	*R*	**0.152**	**0.272**	**0.016**	**0.008**	**0.475**	**0.145**	**-0.08**	**-0.19**	**-0.31**	**1**	**-0.21**	**0.259**	**0.138**	**-0.1**	**0.027**	**-0.09**
	Sig.	0.154	0.01	0.882	0.938	0	0.143	0.424	0.086	0.005	.	0.056	0.029	0.196	0.471	0.786	0.488
	N	89	90	91	91	104	104	94	80	82	104	82	71	90	57	104	65
LNFDIGD1	*R*	**0.063**	**0.027**	**0.118**	**-0.11**	**-0.37**	**-0.21**	**0.454**	**0.175**	**0.208**	**-0.21**	**1**	**-0.22**	**-0.04**	**0.369**	**-0.13**	**-0.02**
	Sig.	0.537	0.796	0.253	0.292	0	0.028	0	0.11	0.058	0.056	.	0.055	0.726	0.005	0.183	0.871
	N	99	95	96	96	106	106	102	85	84	82	106	77	89	57	106	73
Military Spending/GDP 87	*R*	**0.172**	**-0**	**0.207**	**0.171**	**0.399**	**0.137**	**0.027**	**-0.21**	**-0.35**	**0.259**	**-0.22**	**1**	**0.149**	**-0.21**	**-0.06**	**0.081**
	Sig.	0.088	0.973	0.048	0.102	0	0.177	0.8	0.049	0.001	0.029	0.055	.	0.153	0.092	0.552	0.495
	N	99	92	92	92	99	99	94	89	90	71	77	99	94	68	99	74
MILMAN75	*R*	**0.302**	**0.244**	**0.267**	**0.022**	**0.283**	**0.005**	**0.09**	**-0.09**	**-0.21**	**0.138**	**-0.04**	**0.149**	**1**	**-0.28**	**0.093**	**0.162**
	Sig.	0.001	0.01	0.004	0.82	0.001	0.954	0.348	0.339	0.024	0.196	0.726	0.153	.	0.013	0.286	0.113
	N	112	112	114	114	135	135	112	118	119	90	89	94	135	77	135	97
GINI	*R*	**-0.08**	**-0.04**	**-0.38**	**-0.35**	**-0.44**	**-0.23**	**-0.19**	**0.266**	**0.309**	**-0.1**	**0.369**	**-0.21**	**-0.28**	**1**	**0.17**	**-0.37**
	Sig.	0.518	0.742	0	0.001	0	0.042	0.116	0.024	0.008	0.471	0.005	0.092	0.013	.	0.132	0.004
	N	75	90	91	91	80	80	72	72	73	57	57	68	77	94	80	59
FREE1988	*R*	**0.092**	**0.206**	**-0.7**	**-0.48**	**-0.19**	**-0.4**	**-0.25**	**0.413**	**-0**	**0.027**	**-0.13**	**-0.06**	**0.093**	**0.17**	**1**	**-0.31**
	Sig.	0.296	0.018	0	0	0.013	0	0.004	0	0.982	0.786	0.183	0.552	0.286	0.132	.	0.002
	N	130	132	134	134	162	162	132	119	120	104	106	99	135	80	163	100
RORGLAB75	*R*	**-0.15**	**-0.31**	**0.444**	**0.364**	**0.359**	**0.167**	**0.268**	**-0.12**	**-0.17**	**-0.09**	**-0.02**	**0.081**	**0.162**	**-0.37**	**-0.31**	**1**
	Sig.	0.155	0.004	0	0.001	0	0.096	0.011	0.282	0.103	0.488	0.871	0.495	0.113	0.004	0.002	.
	N	88	85	87	87	100	100	90	90	90	65	73	74	97	59	100	100



ABSTRACT

Transnational corporations appropriate "carrying capacity" for the core by transferring the core's hazardous products, production processes, and wastes to the peripheral countries of the world-system. An increasingly important form of this reproduction process is the transfer of core-based hazardous industries to export processing zones (EPZs) located in a number of peripheral countries in Africa, Asia, and Latin America and the Caribbean. A specific case is examined in this paper: the transfer of hazardous industries to the *maquiladora* centers located on the Mexican side of the Mexico-U.S. border. *Maquiladoras* provide an excellent case for examining what is known about the causes, adverse consequences, and political responses associated with the transfer of core-based hazardous production processes to the EPZs of the periphery.

The Transfer of Core-Based Hazardous Production Processes to the Export Processing Zones of the Periphery: The Maquiladora Centers of Northern Mexico

R. Scott Frey

> The bourgeoisie has only one solution to its pollution problems: it moves them around.
>
> Saying adapted from Frederick Engels, cited in Harvey (1996:366)

Some of the core's hazardous products, production processes, and wastes are transferred to the peripheral zones of the world-system by transnational corporations (TNCs).[1] Since few peripheral countries have the ability to adequately assess and manage the risks associated with such hazards, TNC export practices are increasing the health, safety, and environmental risks facing many peripheral countries.[2] Increasingly, many impoverished peripheral states (seeking to attract industry and foreign currency, and promote economic development) have contributed to the risk transfer problem by establishing export processing zones (EPZs). These so-called "free zones" have few regulatory restrictions on pro-

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1. For a sampling of the literature, see Adeola (2001), Castleman (1985a, 1995, 1999), Castleman and Navarro (1987), Clapp (1998a, 2001, 2002a, 2002b), French (2000:71–86), Frey (1995, 1997, 1998a, 1998b, 2001, 2002), and Millen and Holtz (2000). Concern has also centered on the dispersal of pollutants between the core and periphery through the air, soil, water, and other media, as well as the pollution of the global commons by the core countries (see, e.g., Bergesen and Parisi 1999; Dietz and Rosa 1997; Huq 1994; Moomaw and Tullis 1994; Redclift and Sage 1998; Roberts and Grimes 1997; Rosa and Dietz 1998).

2. See, e.g., Brenner, Ross, Simmons, and Zaidt (2000), Brown (2002), Covello and Frey (1990), Kasperson and Kasperson (2001), LaDou (1998), and Millen and Holtz (2000).

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duction practices and offer many other concessions to TNCs. Cost-conscious TNCs have responded by moving production facilities to hundreds of EPZs located in more than sixty countries in Africa, Asia, and Latin America and the Caribbean.[3] In effect, TNCs are appropriating carrying capacity for the core by transferring ("distancing") the core's hazards or anti-wealth to the EPZs of the periphery.

I provide a provisional mapping of the general contours of the problem by examining what is known about a specific case: the transfer of hazardous industries to the *maquiladora* centers located on the Mexican side of the Mexico-U.S. border. The *maquiladoras*[4] (mostly foreign-owned factories using imported materials) provide an excellent case for examining the causes, consequences, and political responses associated with the transfer of core-based hazardous production processes to EPZs located in the periphery. Discussion of this specific case proceeds in five steps. A brief description of the Mexico-U.S. border area is presented in the next section. The major political and economic forces driving the transfer of hazardous industries to cities located on the Mexican side of the border are then charted. The extent to which the location of hazardous industries has increased health, safety, and environmental risks and contributed to other problems in Northern Mexico is examined next. An effort is then made to critically evaluate the increasingly privileged neoliberal contention[5] (and its

3. EPZs are special geographic zones, providing favorable investment and trade concessions to capital. Concessions include tax holidays, exemptions from labor and environmental regulations, provision of infrastructure, duty-free export and import and the free reparation of profits. The United Nations Industrial Development Organization (1980:6) defines an EPZ as:

> ...a relatively small, geographically separated area within a country, the purpose of which is to attract export-oriented industries, by offering them especially favourable investment and trade conditions as compared with the remainder of the host country. In particular, the EPZs provide for the importation of goods to be used in the production of exports on a bonded duty free basis.

For a further discussion, see Chen's (1995) useful account of the evolution of EPZs and other types of free economic zones, as well as Abbott (1997), Dicken (2003), Jauch (2002), and the International Labour Organization (1998).

4. The term is derived from the Mexican colonial word maquila or the fee charged by millers to grind corn into meal (but see Brenner et al. 2000:478, note 1).

5. Neoliberalism is typically defined as "the package of structural adjustments, privatizations and 'free trade' that the first world has been imposing on the third world for the past fifteen years" (Wilson 1997:30) or as "...the hegemonic ideology of core nation-states and of the transnational elite, the means by which the subordinated are consensually dominated. The neo-liberal agenda seeks to achieve the total mobility of capital by advocating the elimination of state intervention in the economy and regulation by individual nation-states of the activity of capital in their territories" (Marshall 1999:257). See also Casanova (1996), Chomsky (1998, 1999), Chossudovsky (1997), McMichael (2000), Otero (1996), and Polanyi (2001/1944).

more sophisticated counterpart, ecological modernization theory) that the transfer of the core's hazardous production processes to the periphery is beneficial to both the core and the periphery. Emerging political responses to the problem are briefly and critically examined in the final section.

THE MEXICO-U.S. BORDER REGION

The U.S. and Mexico share a border that stretches nearly 2,100 miles from the Pacific Coast to the Gulf of Mexico.[6] The border cuts across four U.S. states (California, Arizona, New Mexico, and Texas) and six Mexican states (Baja California, Sonora, Chituahua, Coahuila, Nuevo Leon, and Tamaulipas). The border region, defined as including 60 miles of territory on either side of the border, consists of approximately 250,000 square miles of land.

More than 12 million people were estimated to reside in the border area in 2000: 7 million on the U.S. side and over 5 million on the Mexican side (ITESM and InfoMexus 2002; Peach and Williams 1999). Over 70 percent of the population resides in 14 twin cities; the largest being San Diego-Tijuana, with a population of over 4.5 million. The population of the region has more than doubled since 1980, creating severe pressure on the existing physical infrastructure and the environment. This has taken several forms, including inadequate drinking water, poor sewage services, insufficient housing, improper garbage disposal, and air and water pollution. *Colonias* (unincorporated poor settlements) with inadequate infrastructure and squalid conditions are growing along the border at the rate of 10 percent per year and contain a population estimated to be over 1.5 million (Borderlines 1998a; ITESM and InfoMexus 2002). Economic and other disparities between the two sides of the border are great; the average per capita income on the U.S. side is more than ten times that of Mexico (ITESM and InfoMexus 2002). The border is one of the "hottest growth zones" in North American and one of the busiest in the world; the average number of legal northbound crossings is estimated to be over 200 million per year.[7]

6. See Lorey (1990) and ITESM and InfoMexico (2002) for good overviews of the border region.

7. For excellent discussions of life on the Mexican side of the border, see Berry and Sims (1994), Bowden (1998), Rotella (1998), Simon (1997:chapter 8), and Urrea (1993).

Most of the border region consists of high altitude desert. The region includes three major desert systems (the Sonora, Mojave, and Chihuahua), separated by three mountain ranges (the Sierra de Juaven, the Sierra Madre Occidental, and the Sierra Madre Oriental). Irrigation and rapid population growth in this semi-arid region have placed high demands on the limited water supplies. Surface water is the major source of water for most border cities.[8]

THE POLITICAL ECONOMY OF THE TRANSFER OF HAZARDOUS INDUSTRIES TO THE *MAQUILADORA* CENTERS

Political and economic forces operating at the intranational, international, and supranational levels promote the transfer of core-based hazardous industries to the periphery.[9] In an effort to expand markets and curb production costs, many core-based TNCs have moved hazardous production facilities to sites located in Northern Mexico and elsewhere in the periphery. The Mexican state, like the states of many other peripheral countries, has pursued export-oriented industrial policies to attract industry. In turn, various international organizations such as the World Bank, the International Monetary Fund (IMF), and the World Trade Organization (WTO) multilateral trading system have enacted policies promoting and supporting TNC practices and the export-oriented industrial policies of the Mexican and other peripheral states.

In the Core

Scientific and public concern with the health, safety, and environmental risks of industrial production emerged as an important issue during the 1970s and has continued in the core countries (Andrews 1999:chapter 12; Hays 2000; O'Neill 2000). This concern gave rise to a host of regulations. Early U.S. efforts included the National Environmental Policy Act (NEPA) of 1969, the Occupational Health and Safety Act (OSHA) of 1970, the Federal Water Pollution Control Act of 1972, the 1976 Toxic Substances Control Act, and the Resource Conservation and Recovery Act (RCRA) of 1976. Subsequent legislation such as the 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly known as Superfund), the 1984 amendment to RCRA, and the 1986 Superfund Amendments and Reauthorization Act (SARA) curtailed the haphazard disposal of hazardous wastes into the air and water and increased the amount of wastes earmarked for specialized disposal (Fiorino 1995:22–99). These regulations increased industrial production costs, pushing hazardous industries to the periphery as TNCs attempted to reduce production costs.[10]

The effect of such regulations on the dispersion of hazardous industries to the periphery has been the subject of considerable debate.[11] Several researchers report that the impact of core regulation on the dispersal of hazardous industries has either been exaggerated or is ambiguous.[12] Leonard (1988), for instance, reports that there is little evidence to support the claim that increased regulation has led to the large-scale transfer of hazardous industries ("industrial flight") to so-called "pollution havens" located in the periphery; rather, only certain aging and economically marginal production processes have been exported: benzidine-based dye production, arsenic production, asbestos processing, lead refining, battery manufacturing, and pesticide production. A subsequent U.S. Chamber of Commerce survey of U.S. firms operating in Mexico indicated that firms were not relocating to Mexico to avoid pollution abatement costs (cited in Molina 1993:226). Eskland and Harrison (1997) in an empirical study of Mexico (and three additional countries, including Cote d'Ivoire, Morocco, and Venezuela) report that pollution abatement costs had little effect on industrial country investment in Mexico and little evidence that foreign investment is in "dirty" industries. Grossman and Krueger (1993:38–42), in an important study based on data from the mid-1980s, report that the effects of pollution abatement costs in the U.S. had little effect on *maquiladora* activity in Mexico.

8. For further discussion of the border region, see Brenner et al. (2000), Frumkin, Hernandez-Avila and Torres (1995), ITESM and InfoMexus (2002), and Liverman, Varady, Chavez and Sanchez (1999).

9. Similar processes underlie the distribution of hazards within the core countries and elsewhere (see, e.g., Boone and Modarres 1999; Bryant 1995; Bullard 2000; Camacho 1998; Cohen 1997; Collin 1994; Heiman 1996; Mohai and Bryant 1992; Szasz and Meuser 1997).

10. See, e.g., Castleman (1985a, 1999), Castleman and Navarro (1987), Clapp (1998a, 2001:chapter 5), Jayadevappa and Chhatre (2000), Leonard (1988), and Rock (1996).

11. See, for example, Castleman (1985a, 1985b), Clapp (1998a, 2001:chapter 5), Eskeland and Harrison (1997), Grossman and Krueger (1993:36ff), Jaffe et al. (1995), Leonard (1988), Levenstein and Eller (1985), Low and Yeats (1992), Mol (2001:157–165), Molina (1997:6–14), Nordstrom and Vaughan (1999), Pearson (1987), Rauscher (1997), Roberts (1998), Rock (1996), and Tobey (1990).

12. See Jaffe et al. (1995:143–150), Jayadevapa and Chhatre (2000), Leonard (1988), and Tobey (1990). Chua (1999:408–410) and Rauscher (1997) provide good summaries of much of this work, and Clapp (2001:chapter 5) provides a critical assessment of the research.

Molina (1993), in a follow up study to the Grossman and Krueger (1993) study, reports that during the 1980s as U.S. pollution abatement costs increased, U.S. *maquiladora* investment increased dramatically. A 1991 U.S. Government Accounting Office study found that several Los Angeles furniture manufacturers relocated to Mexico after the establishment of stringent air pollution restrictions in California (Sanchez 1990; U.S. General Accounting Office 1991). It is also interesting to note that many of the U.S. corporations lobbying for the North American Free Trade Agreement (NAFTA) were major polluting industries (Anderson, Cavanagh, and Gross 1993). Or consider the case of General Telephone and Electronics (GTE) Corporation:

> In the mid-1980s more than 200 workers from GTE's Albuquerque, New Mexico plant, many of them suffering from several forms of cancer they claimed were brought on by exposure to workplace solvents, sued the company. During the resolution of the lawsuit, GTE moved the most hazardous section of the plant just across the border to Juarez, Mexico" (Karliner 1997: 155).

And, more recently, Clapp (2001:chapter 5, 2002a) and Rothman (1998) have argued that much of the work reporting little relationship between environmental regulation and industrial relocation is deeply flawed because it is based on old data and fails to take into account all environmental costs.

Factors other than health and environmental regulations have certainly contributed to the movement of industries (hazardous and otherwise) to Northern Mexico and other peripheral countries (Dicken 2003; Rauscher 1997; Wheeler and Mody 1992). These include international economic conditions such as exchange rates and comparative resource endowments; tax avoidance; labor, energy, and transport costs; domestic markets; and overall business investment conditions. The spatial dispersion of hazardous industries also reflects a much larger economic globalization process in which spatial and temporal constraints have been dramatically reduced through advances in transport and communication technologies, as well as supranational organizational and institutional innovations that TNCs played a part in establishing (Ciccantell and Bunker 1998; Dicken 2003; Marshall 1999; Millen, Lyon, and Irwin 2000:233–241). This, in turn, is energized by a resource and energy system that is increasingly global in nature (Clark 1998).

Whatever the relative importance of these interrelated forces, the point is that core-based TNCs have found it economically advantageous and increasingly possible to transfer hazardous industrial activities to the border cities of Northern Mexico and export processing zones located elsewhere in the world. Production costs are relatively low in Mexico because of low wages, cheap resources and energy; low taxes and other subsidies; and limited state control of

the environment and the health, safety, and well-being of its citizens. Reduced costs in Mexico enhance the competitiveness of TNCs and promote capital accumulation. In other words, capital flows to peripheral countries like Mexico having what Daly (1996:153) calls an "absolute advantage" in industrial production.

In the Periphery

Faced with poverty and the resulting political pressures, debt and structural adjustment pressure from the International Monetary Fund and the World Bank, low agricultural and mineral commodity prices, and a world-system marginalizing them economically and politically, many peripheral states have pursued export-oriented policies in an effort to attract industry from the core (see Dicken 2003).[13] In fact, many peripheral countries are so anxious to industrialize that they are willing to accept almost any industry offered: hazardous or otherwise. Nowhere is this pattern more pervasive than in Mexico.

The history of economic ties between the U.S. and Mexico is complicated and conflicted (Hart 2002). During World War II, for instance, a large number of Mexican workers replaced U.S. workers serving in the armed services. The Bracero Program of 1942 legalized this migration, allowing Mexican workers to migrate to the U.S. to perform temporary agricultural work and railroad construction. The U.S. government canceled the program in 1964. Several hundred thousand workers returned to Mexico, increasing unemployment and overcrowding in the border cities (Sklair 1993).

The Mexican state established the Border Industrialization Program (BIP) in 1965 to cope with the economic problems along the border (Schwartz 1987). The purpose of the program was to promote industrialization, employment, and new technology imports and management practices. *Maquiladoras* were allowed to import equipment, components, and raw materials duty free for assembly and export to the U.S. and other countries.[14] Cheap labor, lax regulation, generous tax incentives, and close proximity to the U.S. consumer market drew many TNCs, initially from the U.S. and later from Canada, Taiwan, Japan, Mexico, South Korea, and fifteen other countries, including Germany, France, Holland,

13. These include deregulation and privatization of the economy, removal of trade restrictions, wage compression, and liberalization of controls on capital movement.

14. A 1962 U.S. customs regulation, Item 807.00 of the Tariff Schedule of the United States, allowed U.S. companies to export U.S. materials to other countries for assembly and reimport the product and pay only duty on value added to the product.

Italy, Sweden, Spain, Australia, Singapore, Ireland, Finland, England, Malaysia, Columbia, Belgium, and Argentina. The program was expanded to the non-border areas (except for three cities: Mexico City, Guadalajara, and Monterrey) after 1972 (Gabriel 1990; Sklair 1993:chapter 3).

The number of *maquiladoras* grew steadily during the 1960s and 1970s. Growth expanded dramatically in the mid-1980s when the Mexican state liberalized trade and enacted other measures in an effort to deal with serious economic problems.[15] Mexico entered the General Agreement on Tariffs and Trade (GATT) in 1986, liberalizing trade restrictions and opening the country to the global economy. The state abandoned many policies that restricted TNC activities, reduced protectionist tariffs, curbed labor unions, limited minimum wage increases, and promoted the *maquila* industry in diverse ways (Wilson 1992:40ff). Labor costs were reduced significantly (making Mexican wages some of the lowest in the world) when the peso was devalued repeatedly during the 1980s and the early to mid-1990s as the Mexican state attempted to meet its debt obligations under IMF-sponsored structural adjustment (George 1992:24–28; Wilson 1992).

The number of *maquiladoras* grew dramatically in the 1990s, increasing from 1,818 in 1990 to 3,486 in early 2000. More than eighty percent of all *maquiladoras* are located in the northern border area of Mexico. Employment doubled during the 1990s; it stood at more than 1,200,000 in 2000 but it has declined somewhat due to the downturn in the U.S. economy starting in early 2000 and the movement of some jobs to China and elsewhere (Greider 2001; Hanson 2002). (See Table 1.) *Maquiladoras*—a major source of foreign exchange and employing twenty-five percent of the manufacturing labor force in the country—have not only changed in number and importance since the 1960s, but they have changed qualitatively by moving from simple assembly to manufacturing (Gereffi 1996; Hanson 2002). The present breakdown of employment by industry type is as follows: textiles (24%), electric and electronic materials and accessories (30%), wood and metallic furniture and parts (5.6%), services (22%), electric and electronic equipment and machinery (4.6%), chemical products (10.6%), food processing (2.3%), and other manufacturing (1.3%) (ITESM and InfoMexus 2002: 85). Despite the increasing sophistication of production processes in many of the newer *maquiladoras*, labor-management practices of the core country factories have not been fully transferred (Hanson 2002; Kenney et al. 1998).

15. See Pastor and Wise (1994) for a good discussion of why liberalization was undertaken.

Table 1 – Number of *Maquiladora* Plants and Employees in Mexico by Year

Year	Number of Plants	Number of Employees
1967	72	4,000
1970	160	20,000
1975	454	62,200
1980	620	119,600
1985	760	212,000
1990	1,818	441,000
1995	2,138	497,000
1998	3,107	1,056,783
1999	3,436	1,196,678
2000	3,486	1,216,819

Source: Adapted from Sklair (1993:54, 63, 68, 241) and http://www.nafta-mexico.org

Plant owners represent a virtual "Who's Who" of international capital: Alcoa, BMW, Chrysler, IBM, RCA,[16] General Motors, ITT, DuPont, Hughes Aircraft, Eastman Kodak, Canon, Wal-Mart, JVC, Sara Lee, Zenith, Xerox, Sony, Motorola, General Electric, Toshiba, Ford, United Technologies, Mattel Toys, Matsushita, Hitachi, and other lesser known U.S., Canadian, European, Japanese, South Korean, and other TNCs. (See Table 2 for a listing of the 50 largest companies and the nature of their production processes.) Various consumer products are produced for export, including furniture for several U.S. companies, auto parts for Chrysler, high-tech electronic components and computer disks for Sony, Ford automobiles, Foster Grant sunglasses, hospital gowns for Kimberly Clark, and garage door openers for Sears. *Maquila* plants also produce hazardous wastes and other substances that are not managed effectively and contaminate the air, water, and soil, as well as put workers and others at risk of death, disease, and injury (e.g., Clapp 2002a; Liverman et al. 1999; Mumme 1999), but more on this below. Some of the TNCs have introduced health, safety, and environmental standards that are equivalent to those of the developed countries, but many TNCs have not introduced such standards (Castleman 1995, 1999; see also Garcia-Johnson 2000:chapter 5).

16. The story of RCA's involvement in Northern Mexico provides a fascinating tale of one company's effort to reduce production costs (see Cowie 1999:chapters 4–7).

Table 2 – Mexico's Fifty Largest *Maquiladora* Companies, 2002

Rank 2002	Company	Employees	No. Plants in Mexico	Country of Origin	Industrial Sector
1	Delphi Automotive Systems	39478	28	USA	Automotive
2	Yazaki Corporation	14572	12	Japan	Automotive
3	Offshore International	11615	1	Mexico	Shelter Services
4	Thomson Consumer Electrinics (RCA)	10874	6	USA	Electronics
5	Ford Motor Company	10024	7	USA	Automotive
6	Sony Corporation of America	9679	4	Japan	Electronics
7	Kemet Corporation	9200	8	USA	Electronics
8	Lear Corporation	8569	8	USA	Automotive
9	Alcoa Fujikura LTD	7650	8	Japan	Automotive
10	TYCO International LTD	6785	4	USA	Electronics Medical
11	A.O. Smith Corporation	6598	8	USA	Electrical
12	Carolina Coupon Clearing Inc.	6542	5	USA	Services
13	Sanmina-Sci	6300	7	USA	Electronics
14	General Electric Company	5965	7	USA	Electrical
15	Sanyo North America Group	5879	2	Japan	Electronics
16	Samsung Tijuana Park	5789	3	Korea	Electronics
17	Breed Technologies, INC	5687	9	USA	Automotive
18	Emerson Electric Co.	5678	7	USA	Electrical
19	American Industries	5332	22	Mexico	Shelter Services
20	Matsushita Electric Corp. of America	4986	4	Japan	Electronics
21	Sumitomo Wiring Electric Systems	4879	6	Japan	Electrical
22	Daewoo Industrial Co., LTD	4856	3	Korea	Electronics
23	General Instruments Corporation	4589	3	USA	Electronics
24	Seagate Technology Inc.	4582	4	USA	Electronics
25	Johnson and Johnson Company	4569	5	USA	Medical
26	TRW Incorporation	4554	5	USA	Automotive
27	Philips Electronics	4387	8	Netherlands	Electronics
28	Allegiance Corporation	4289	5	USA	Medical
29	Collectron of Arizona, Inc.	4256	3	USA	Services
30	Attel Dell Norte S.A De C.V	4238	1	USA	Electronics
31	ITT Industries	3845	4	USA	Automotive
32	Hitachi Home Electronics	3700	3	Japan	Electronics
33	Johnson Controls, Inc.	3589	7	USA	Automotive
34	Leviton Manufacturing Company	3256	4	USA	Electrical
35	Quirk Wire Co.	3120	2	USA	Electronics
36	Scientific Atlanta Incorporation	2996	1	USA	Electronics
37	Strattec Security Corporation	2879	1	USA	Automotive
38	Avery Dennison	2830	2	USA	Office Products
39	International Business Machines (IBM)	2689	1	USA	Electronics
40	Intermex Manufactura	2600	9	Mexico	Services
41	Levi Strauss & Co.	2598	2	USA	Apparel
42	Nova Link	2591	2	USA	Textile
43	Allied Signal Co.	2589	4	USA	Automotive
44	AVX Corporation	2587	2	USA	Electronics
45	Mattel Inc.	2578	1	USA	Toys
46	Honeywell Incorporation	2489	3	USA	Electronics
47	Optek-Danulat Inc.	2488	2	Germany	Medical
48	Advance Transformer Co.	2387	3	USA/Holland	Electronics
49	Hamilton Proctor-Silex Inc.	2331	3	USA	Appliances
50	Yale De Mexico S.A. De C.V.	2169	1	USA	Apparel

Source: http://www.maquilaportal.com

The North American Free Trade Agreement (NAFTA), an executive agreement reached in August 1992 and enacted on January 1, 1994, has set the stage for the removal of most remaining tariff barriers in Mexico over the next decade (Cameron and Tomlin 2002). *Maquila* activity has grown rapidly under NAFTA and it is expected to continue, though there has been a slow down recently as noted above (Hanson 2002). More TNCs will likely locate production facilities in the interior of Mexico to take advantage of lower production costs, but plant growth will continue along the border region.

ADVERSE CONSEQUENCES

Hazardous industrial production can damage the environment and adversely affect human health through occupational exposure and environmental dispersion of hazardous wastes and substances in the soil, water, and air or large-scale failures such as explosions and fires. Numerous undesirable social and economic consequences are also associated with hazardous industries, including staggering economic costs and an inequitable distribution of costs and benefits.[17]

17. Covello and Frey (1990), LaDou (1998), Liverman et al. (1999), McCally (2002), Pearce et al.(1994), and World Resources Institute (1998:51–72) provide a good overview of the issues.

Peripheral countries like Mexico are particularly vulnerable to the risks posed by hazardous industries because of a young, poorly-trained, uninformed, undernourished, and unhealthy workforce (Kourous 1998; Lanrigan and Garg 2002; Ostrosky-Wegman and Gonsebatt 1996). Other problems exist, including limited public awareness of the risks associated with hazards, weak and tightly controlled labor unions, politically unresponsive state agencies, and inadequate risk assessment and management capabilities (Meredith and Brown 1995; Pena 1997:28ff; Sanchez 2002). In addition, organized environmental activism is limited because potential participants have little time for such activity since they work six days a week and there are few channels through the courts or legislature for effective public participation (Barkin 1991; Mumme 1998). Structural adjustment reforms and trade liberalization as well as the general processes of globalization have compounded the problem by increasing some of the problems mentioned above and reducing the state's right/ability (or "infrastructural power" according to Tilly [1995:14]) to regulate the domestic market, the environment, and the health and safety of workers (Casanova 1996; Millen and Holtz 2000). The problem is compounded by the fact that hazardous industries are located in rapidly growing cities or "boom towns" faced with many health, safety, and environmental risks and inadequate infrastructure and services in terms of health care, housing, water, electricity, sewage and drainage, and garbage collection and disposal (Brenner et al. 2000; Liverman et al. 1999; World Resources Institute 1996:1–156). In other words, "throughput"[18] is greater than the regeneration and absorptive capacities of the Mexican border cities.

Environmental Risks

Emissions of toxic substances, the improper disposal of hazardous wastes and materials, and the rapid population growth and increased human activity associated with the growth of *maquiladoras* contribute to the risk of environmental damage. Environmental damage takes numerous forms: soil contamination, soil erosion, groundwater pollution and depletion, biodiversity loss, contamination of rivers and coastal regions, air pollution, threats to plant and animal health and survival, and changes and variability in climate.[19] Since reliable data do not exist on the full scope and nature of the problem in Northern Mexico, it

18. Daly's (1996:28) term for "the flow beginning with raw material inputs, followed by their conversion into commodities, and finally into waste outputs."

19. Human impact on the environment in the border region has a long history. See Melville (1994) for a fascinating account of the adverse environmental consequences associated with the introduction of European grazing animals in 16th Century Mexico.

is not possible to estimate the full extent of the environmental damage (ITESM and InfoMexus 2002; Liverman et al. 1999; Pena 1997:283–296). Such damage is a potentially important problem because it can deplete important natural resources, disrupt the stability of larger ecosystems, and threaten human health (Brenner et al. 2000; Simon 1997). Effects are not only local, but global because *maquila* activities are embedded in global commodity chains stretching across time and space. Pena (1997:295) describes the situation in the following fashion:

> A global ecological perspective on the maquilas leads to the inescapable conclusion that these industries are contributing to the ravages of natural resource extraction in many parts of Mexico and the rest of the world. The sources of inputs for maquila production are dispersed throughout the globe. For example, the aluminum, copper, tin, steel, ceramics, and plastics contained in maquila assembly components come from mining, milling, and fabrication in North America, Indonesia and other parts of Southeast Asia, Africa, and South America.

Consider what is actually known about environmental risks (see, e.g., Liverman et al. 1999). Water shortages have resulted from rapid population growth and increased industrial activity in the *maquila* centers (Kelly and Solis 2001). The *maquilas* have also contributed to water pollution on both sides of the border; industrial waste water is seldom treated before it is discharged into rivers, arroyos, the Gulf of Mexico, the Rio Grande, and the Pacific Ocean (ITESM and InfoMexus 2002; Pena 1997:283–296; Simon 1997:chapter 8). Air pollution is also a serious problem, for ozone, sulfur dioxide, carbon monoxide, and nitrogen dioxide are high on both sides of the border (ITESM and InfoMexus 2002; Liverman et al. 1999; Sanchez 1990, 1991). *Maquiladoras* generate a substantial amount of hazardous waste (including solvents such as trichloroethylene, acids, heavy metals like lead and nickel, paints, oils, resins, and plastics) that goes untreated and is unaccounted for, despite fairly stringent laws in the U.S. and Mexico.[20] Despite the existence of a binational agreement (the La Paz Agreement) requiring U.S. companies to return wastes associated with the use of toxic materials, only 25% of such wastes were returned and 65% of such wastes were unaccounted for in either the U.S. or Mexico in the 1990s (Perry, Sanchez, and Glaze 1998). The situation is worse now because as of January 1, 2001 NAFTA no longer requires TNCs to return waste to the U.S. U.S. hazardous wastes have also been transported to *maquiladoras* and recycling plants

20. See Barry (1994), Davis and Perez (1989), Mumme (1999), Reed (1998), Sanchez (1990, 1991), and Varady, Lankao, and Hankins (2001) for a useful overview of the issues.

for storage and abandoned or dumped illegally in the desert and other locations (Clapp 2002a; Reed 1998; Simon 1997:208ff). The most recent estimates are that the waste flow from the U.S. to Mexico (230,417 tons in 1996 and 254,500 tons in 1999) was 20 to 30 times more than waste shipped to the U.S. from Mexico (Jacott, Reed, and Winfield 2001; Reed 1998).[21]

Human Health Risks

Occupational and environmental exposure to the hazards posed by industry and the attendant health consequences are not fully known (Brenner et al. 2000; Carter et al. 1996; ITESM and InfoMexus 2002; Liverman et al. 1999). Given the experiences of the core countries and reports from many peripheral countries, hazardous industries pose a serious threat.[22] Those exposed are at a high risk of death, disease, and injury because of their increased susceptibility to various site-specific cancers, skin irritation, respiratory problems, neurobehavioral problems, reproductive risks such as birth defects and miscarriages, genetic changes and damage to the immune system, and acute and chronic damage to specific body organs. In addition, those living near hazardous facilities are at increased risk of death and injury from fires and explosions (Levy 1995).

Since reliable data do not exist on the occupational and environmental exposure to the routine, fugitive, and accidental emissions of hazardous substances from *maquiladoras*, it is not possible to estimate the actual number of deaths or cases of disease and injury that can be attributed to them. It is quite clear, given what we know about the environmental risks discussed above, that health problems linked to the *maquila* plants are pervasive. Air pollution and groundwater and surface water contamination have been documented at many points along the border. Hazardous waste management is also a severe problem, for many plants dump and store hazardous wastes in a haphazard fashion. Industrial accidents and the adverse health and safety conditions facing *maquila* workers and the inhabitants of *colonias* surrounding the plants are serious.[23]

21. The problem is so serious that the Sierra Club estimated in 1993 that it would cost over 20 billion dollars to clean up hazardous wastes along the border (cited in Cobb 1995:88). The current clean-up cost would be substantially higher.

22. See, e.g., Abbott (1997), Barry and Sims (1994), Barten et al. (1996), Brown (2002), Castleman (1985a), Frey (1998b), LaDou (1992), Levy (1995, 1998), National Research Council (1991), and Pearce et al. (1994).

23. Barry and Sims (1994), Borderlines (1998), Brenner et al (2000), Gallagher (2002), Kochan (1989), Kourous (1998), Moure-Eraso et al. (1994, 1997:591, 596), Multinational Monitor (1995), Pena (1997:296–303), Sanchez (1991), Reed (1998), Simon (1997:chapter 8), and Warner (1990) provide a good review of the situation.

Current research indicates that the rate of nonfatal occupational injuries and illnesses among *maquiladora* workers is substantially higher than that of U.S. workers (Brenner et al. 2000:274–275). Adverse health effects (including low birth weight infants, stress, fatigue, headaches, cumulative trauma disorders, and the like among *maquila* workers) have been reported by several researchers.[24] Noncommunicable diseases are also a problem, for mortality rates for general cancer and several site-specific cancers (including trachea, bronchitis, and lung) as well as congenital anomalies are higher along the Mexican border than for the country as a whole (Brenner et al. 2000:285). Numerous incidents have been reported, but none more dramatic than the cluster of 50 anencephalic babies born in the Brownsville, Texas-Matamoros, Mexico area (19 in Brownsville and 31 in Matamoros) in the early 1990s (Suro 1992).

Infant mortality and age-adjusted general mortality rates on the Mexican side of the border are not only higher than rates on the U.S. side but higher than rates for Mexico as a whole (Brenner et al. 2000:280–287). Differences are even greater for rates of mortality and/or morbidity for infectious diseases such as tuberculosis, hepatitis A, typhoid fever, dengue, and so on. In fact, "…Mexico's border states account for only one-sixth of that country's population but, according to recent data from the Secretary of Health, produced 61 percent of the TB cases reported in Mexico during the first ten weeks of 1998" (Borderlines 1998b: 1). Such disparities can be attributed to the rapid population growth and limited infrastructure development and unmet service needs in the border cities along the Mexican side of the border (Brenner et al. 2000).

The health problems posed by the *maquila* plants (and the rapid population growth and related factors associated with increased *maquila* activity) are so serious that the Council on Scientific Affairs (1990:3320) of the American Medical Association concluded that "environmental monitoring and disease incidence data…point out that the public and environmental health…is rapidly deteriorating and seriously affecting the health and future vitality on both sides of the border." John Cavanagh (1992:8), an analyst at the Washington D.C. based Institute of Policy Studies, noted: "…exposure of workers to dangerous toxic substances, and contamination of drinking water with industrial pollutants have turned the Mexican side of the border into an environmental wasteland and industrial slum." The National Toxics Campaign has described the border as "…a two-thousand mile long Love Canal" (cited in Cavanagh 1992:8). And

24. Eskenazi et al. (1993), Meservy et al. (1997), and Moure-Eraso et al. (1997), but see Guendelman and Silberg (1993) and Guendelman et al. (1998).

things have not improved since the implementation of NAFTA (Gallagher 2002; Sanchez 2002).

Economic Costs

The costs associated with the cleanup of contaminated sites and improperly disposed wastes in Mexico are high. The treatment and compensation of the victims of hazardous exposures are potentially very costly. Destruction of marine life, biodiversity, soil, water and air quality, and other natural resources is also likely to be costly. This is a particularly important issue because water is such a scarce commodity in this semi-arid region. Reductions in human health are costly, and they can impede future economic growth (Bloom and Canning 2000; Price-Smith 2001). These and other tangible and intangible economic costs associated with the transfer of hazardous industries appear to be substantial.[25]

Social Costs

Contrary to Beck's (1992, 1999) "risk-society" hypothesis, the bulk of the costs or risks associated with the transfer of hazardous production facilities to Mexico (and other peripheral countries for that matter) are distributed in an uneven fashion (Brenner et al. 2000), representing a pattern of "risk discrimination" (Kasperson and Kasperson 2001). Most benefits go to the core-based TNCs who control production and marketing of products and the profits of their sale, while Mexico bears most of the costs (Cooney 2001; Pena 1997; Sklair 1993).[26] Losses within Mexico are distributed in an unequal fashion: some groups (especially the state and local capital) are able to capture the benefits and other groups (especially those marginalized by gender, age, class, race/ethnicity, and geographic location, including *maquiladora* workers, *colonia* dwellers, and other poor residents) bear the costs (e.g., Brenner et al. 2000; Pena 1997; Simon 1997:chapter 8). Wages are low, averaging twelve dollars a day. Young women employed in the *maquiladoras*, who represent slightly more than 50 percent of the work force currently, have borne many of the health and safety risks associated with hazardous industrial production, but they have enjoyed few, if any, of the economic benefits.[27] Women employed in the electronics industry, for instance, are routinely exposed to solvents that can cause menstrual and fertility problems, as well as cancer and liver and kidney problems. Women working in the *maquiladoras* also experience a variety of other adverse consequences, including discrimination in terms of hiring, wages, and promotion; routine pregnancy tests and systematic firing if found to be pregnant; sexual harassment and abuse on the job; and risk of rape and death in the early mornings when traveling to and from work.[28]

Hazardous residues may move across national borders through the air, water, and food. As noted above, wastes created in the *maquiladoras* are regularly dispersed into the air and water and often end up in the U.S. (Varady et al. 1995). Weak regulatory standards in Mexico also give TNCs leverage in their efforts to reduce labor and other costs in the core countries. And, most importantly, future generations will bear costs and enjoy few of the benefits generated by hazardous industry.[29]

EVALUATING THE COSTS AND BENEFITS

Are the costs associated with the transfer of core-based hazardous industries to the periphery offset by the economic and other benefits as proponents of neoliberalism (Grossman and Kruger 1993) and ecological modernization theorists (Mol 2001) suggest? This is a vexing question because it is difficult to identify, estimate, and value the costs and benefits associated with hazards in monetary terms (Dietz, Frey, and Rosa 2001). Despite suggestions and efforts to the contrary (e.g., Logan 1991), there is no widely accepted factual or methodological basis for identifying, estimating, and valuing the costs and benefits associated with the flow of core hazards to the periphery. Even if the consequences of hazardous exports could be meaningfully identified and estimated, there remains the question of valuing them in monetary terms. The usual strategy is to look to the marketplace for such a valuation, but adverse health, safety, environmental,

25. See Daly's (1996:chapters 10 and 11) discussion of the costs of free trade.

26. One is reminded of a comment by Chomsky (1998:357) regarding the nature of economic development experiments under colonialism and the current neoliberal project:

> …the designers seem to come out quite well, though the experimental subjects, who rarely sign consent forms, quite often take a beating.

27. See, e.g., Abbott (1997), Cravey (1998), Kopinak (1996), Kourous (1998), LaBotz (1994), Park (1993), Tiano (1987, 1994), and Wright (1999).

28. Cevallos (2003), Fernandez-Kelly (1989), Human Rights Watch (1999), Kenney et al. (1998), Moure-Eraso et al. (1997), Parikh (1998), and Pena (1997) provide good summaries of what is known. For an excellent discussion of the life histories of women working in the *maquiladoras* of Tijuana, see Prieto (1997).

29. As several analysts have noted: "…the present generation is only a caretaker of the human genome of future generations" (cited by Ostrosky-Wegman and Gonsebatt 1996:601).

and social consequences are not traded in the marketplace. Efforts have been made to deal with this problem by using either expert judgment or public preferences (Manning, Lawson, and Frymier 1999; Mitchell and Carson 1989), but these techniques are deeply flawed (Dietz et al. 2001; Foster 2002a).

Comments contained in an often quoted 1991 memo by former World Bank Chief Economist Lawrence Summers (The Economist 1992)[30] are worth quoting at length because they illustrate some of the difficulties and contradictory outcomes of applying traditional economic reasoning to the transfer of hazardous industries to the periphery:

> Just between you and me, shouldn't the World Bank be encouraging *more* migration of the dirty industries to the LDCs? I can think of three reasons:
>
> (1) The measurement of the costs of health-impairing pollution depends on the forgone earnings from increased morbidity and mortality. From this point of view a given amount of health-impairing pollution should be done in the country with the lowest cost, which will be the country with the lowest wages.
>
> (2) The costs of pollution are likely to be non-linear as the initial increments of pollution probably have been very low cost. I've always thought that under-polluted countries in Africa are vastly under-polluted; their air quality is probably…low compared to Los Angeles or Mexico City.…
>
> (3) The demand for a clean environment for aesthetic and health reasons is likely to have very high income-elasticity. The concern over an agent that causes a one-in-a-million chance in the odds of prostate cancer is obviously going to be much higher in a country where people survive to get prostate cancer than in a country where under-5 mortality is 200 per thousand. Also, much of the concern over industrial atmosphere discharge is about visibility of particulates. These discharges may have little direct health impact. Clearly trade in goods that embody aesthetic pollution concerns could be welfare enhancing. While production is mobile the consumption of pretty air is a non-tradable.

Such reasoning undervalues nature and is based on the assumption that human life in the periphery is worth much less than in the core because of wage differentials (Foster 2002b; Swaney 1994). Although most costs are borne by the periphery and most benefits are captured by the core-based TNCs and by elites located in the periphery, the costs to the periphery are deemed minimal and

30. He is currently President of Harvard University, former Chief Economist of the World Bank, former U.S. Treasury Secretary under Clinton, and nephew of Paul Samuelson and former son-in-law of Kenneth Arrow, both winners of the Nobel Prize in economics.

acceptable because life is defined as worth so little.[31] Or, as Herman Daly (1993: 57) has noted: "By separating the costs and benefits of environmental exploitation, international trade makes them harder to compare."

Even if the economic costs and benefits associated with the transfer of hazardous industries could be estimated and valued in a meaningful fashion, it is doubtful that the benefits accruing to Mexico would cover the costs. Consider, for instance, Sklair's (1993:240–266) important assessment of the *maquiladora* program. Using six development criteria (backward and forward linkage creation, foreign currency earnings, personnel upgrading, technology transfer, work conditions, and environmental conditions), Sklair concludes that the mix of costs and benefits of the *maquiladora* program is highly uncertain. He notes:

> The end of the maquila industry as we know it would be extremely painful for the frontera norte and for the border communities of the U.S., but in the long-term unless the Mexican government and the TNCs can work out ways of transforming it into a more potent instrument for the development of Mexico and the advancement of its people, Mexico is better off without it" (Sklair 1993:238).

He argues that the situation is unlikely to improve under NAFTA (Sklair 1993: 240–263). Other analysts (e.g., Cooney 2001; Cravey 1998; Kopinak 1996; Pena 1997:chapter 9) have drawn conclusions similar to those of Sklair (1993) or concluded that the Mexican situation is worse after NAFTA (Anderson and Cavanagh 1996; Brenner et al. 2000; Clapp 2002; Gallagher 2002). Gallagher (2002:

31. For further discussion of these and related issues, see Foster (1995, 2002b) and Harvey (1996:366–369). Harvey's (1996:368) provocative comments are worth repeating at length:

> Though the 'impeccable economic logic' advanced by Summers is not hard to deconstruct as the characteristic discourse of a particular kind of political-economic power and its discriminatory practices, it unfortunately approximates as a description of what usually happens. The market mechanism 'naturally' works that way. Property values are lower close to noxious facilities and that is where the poor and the disadvantaged are by and large forced by their impoverished circumstances to live. The insertion of a noxious facility causes less disturbance to property values in low income areas so that an 'optimal' lowest cost location strategy for any noxious facility points to where poor people live. Furthermore, a small transfer payment to cover negative effects may be significant to and therefore more eagerly accepted by the poor, but largely irrelevant to the rich, leading to what I long ago referred to…as the 'intriguing paradox' in which 'the rich are unlikely to give up an amenity at any price whereas the poor who are least able to sustain the loss are likely to sacrifice it for a trifling sum.' If, as is usually the case, areas where low-income, disempowered, and marginalized 'others' live are also zones of more political organization, and weak political resistance, then the symbolic, political, and economic logic for the location of noxious facilities works in exactly the way that Summers' memo envisages.

119), for instance, indicates that "industrial air pollution is outstripping trade-led economic growth in Mexico."

Stoddard (1991) has qualified such views by noting that *maquiladoras* vary considerably in their developmental consequences and many *maquiladoras* are far better than many domestic facilities in the formal and informal sectors. And ecological modernization theorist Arthur Mol (2001:127–130) suggests the environmental provisions and side agreements of NAFTA provide the institutional basis for improvements in the future. But a crucial fact remains: the *maquiladora* industry has had little impact on Mexico's economic development beyond the creation of jobs (many of which are unskilled, though this has begun to change somewhat) and increased revenues from exports.

Complicating the situation is Cooney's (2001:14) observation about the fragility of *maquila* jobs:

> …Mexico is not in control of the wealth generated within the country. The question remains, therefore, as to whether *maquiladora* development can be counted on to provide growth in the long run. Consider a scenario where *maquiladora* workers demand higher wages (perhaps something closer to 1/4th instead of 1/12th of their US counterparts) or insist that health and safety standards be the same as in the US, or request that working overtime be optional. It is probable that the capital accumulated by many of these TNCs may continue their circuit elsewhere. In other words, although the surplus is generated in Mexico, it can be relocated at the time of re-investment, if the conditions do not remain sufficiently propitious for capital.

Greider (2001) and Smith (2002) have commented on the emergence of such a pattern in late 2001, noting that a number of "footloose" TNCs have been moving their production facilities from Mexico to China, Vietnam, and elsewhere.

Princeton economists Grossman and Krueger (1993) tell another story; they examined the developmental consequences of *maquiladoras* in environmental terms. They present findings of cross-national research[32] suggesting the existence of a curvilinear relationship between national economic development and several measures of urban environmental degradation. They report that as economic development increases, environmental degradation per unit of economic development decreases; this is the so-called inverted U-curve or environmental Kuznets curve hypothesis (EKC) named after economist Simon Kuznets's (1955) work on economic growth and income inequality. They argue that Mexico is on the verge of such a threshold: future economic growth (especially under NAFTA) will improve environmental management and reduce environmental

32. Others have also presented such findings, including Dietz and Rosa (1997), Roberts and Grimes (1997), and the World Bank (1992).

problems (Grossman and Krueger 1993).[33] For proponents of neo-liberalism, and their ecological modernization counterparts (Mol 2001), the benefits will outweigh the costs in the future.

The problem with Grossman and Krueger's argument is that they assume that the cross-national relationship between aggregate economic output and environmental degradation is a result of intracountry changes in consumption, values, regulation, and technology resulting from affluence. But as Rosa and Dietz (1998:436) note:

> A less optimistic explanation is that the new international division of labor has shifted the most environmentally disruptive activities to the least affluent nations, leaving relatively clean service industries in the most affluent nations. Reduced environmental impact from industries in the affluent nations is thus an artifact occurring for other reasons; the impacts are still taking place, but have been shifted to politically less powerful locations.

Roberts and Grimes (1997, 1999:67) also dismiss the modernization implications of the environmental Kuznets curve; they assert that the curve is not a historical trend but a temporary pattern confined to the 1980s (Roberts and Grimes 1999: 67). Arrow et al. (1995:520) make similar arguments and note that the existence of the inverted-U curve (which they correctly note does not exist for resource stocks) "…does not constitute evidence that it will happen in all cases or that it will happen in time to avert the important and irreversible global consequences of growth."[34] Stern (1998), in an extensive review of the exiting literature, raises

33. Grossman and Krueger (1993:48) also claim that trade liberalization under NAFTA "may well increase Mexican specialization in sectors that create less than average amounts of environmental damage." Like many other free traders (and those embracing an ecological modernization perspective [e.g., Mol 2001; Stoddard 1991]), they argue that the older and often inefficient domestic factories (that arose under the Import Substitution Industrialization program of the past) will be replaced by more efficient and cleaner industries. This, of course, remains an open question, for Molina (1993) has presented convincing evidence that dirty industries located in the U.S. have moved to Northern Mexico.

34. Arrow et al. (1995:521) go on to note:

> Economic growth is not a panacea for environmental quality; indeed, it is not even the main issue. What matters is the content of growth—the composition of inputs (including environmental resources) and outputs (including waste products). This content is determined by, among other things, the economic institutions within which human activities are conducted. These institutions need to be designed so that they provide the right incentives for protecting the resilience of ecological systems. Such measures will not only promote greater efficiency in the allocation of environmental resources at all income levels, but they would also assume a sustainable scale of economic activity within the ecological life-support system. Protecting

a host of important questions about the validity of the environmental Kuznets curve. More recently, York, Rosa, and Dietz (2003) present compelling cross-national evidence that affluence (GDP/capita) has a positive and monotonic effect on a measure of environmental impact (the ecological footprint measure developed by Wackernagel and Rees [1996]) that takes into account a country's domestic and international impact. Others (see, e.g., Nordstrom and Vaughan 1999; Rothman 1998) have drawn similar conclusions. In sum, the costs of the transfer of hazardous production processes to the periphery appear to outweigh the benefits.

"COUNTER-HEGEMONIC GLOBALIZATION": RESISTANCE THROUGH TRANSNATIONAL NETWORKS?

Efforts to curb the adverse consequences associated with the *maquiladora* industries in Northern Mexico and hazardous industries in EPZs located elsewhere in the periphery have taken several distinct forms: various national regulatory efforts; bilateral and multilateral environmental agreements; trade treaties such as NAFTA and attendant side agreements, including the North American Agreement on Environmental Cooperation (NAAEC) and the North American Agreement on Labor Cooperation (NAALC); various market-based initiatives centering on the modernization of industrial production; industry-led initiatives such as the International Organization for Standardization's ISO 14000 environmental management standards and the International Chamber of Commerce's Business Charter for Sustainable Development; and calls for various supranational bodies such as a "World Environment Organization."[35] These efforts to globalize responsibility or "fill in the space between laws" (Michalowski and Kramer's 1987) are problematic because of noncompliance and weak implementation and enforcement capacity at the national and supranational levels,

> the capacity of ecological systems to sustain welfare is of as much importance to poor countries as it is to those that are rich.

See Mol (2001:chapter 7, especially pp. 163–164) who draws a different conclusion from the existing research.

35. These and other recommendations are discussed in Caldwell (2002), Carter et al. (1996), Castleman (1995), Clapp (2001:chapter 6), French (2002), Gallagher (2002), Garcia-Johnson (2000:chapter 5), LaDou (1998:1720–1722), Liverman et al. (1999: 621–637), Lofstedt and Sjostedt (2001), Millen and Holtz (2000:213–219); Mol (2001: chapters 5 and 7), Moure-Eraso et al. (1997:598–599), Permanent Peoples' Tribunal on Industrial Hazards and Human Rights (1996), Roberts (1996, 1998), Roht-Arriaza (1995), Sanchez (2002), and Varady and Suk (1996).

resulting from fragmentation of efforts, limited resources, increased capital mobility, and the neoliberal project that frames regulation as a trade barrier.[36]

Several analysts have called for more stringent measures, including what some call "the renationalization of capital" (Cobb 1995; Daly 1996:145–162) or the dismantling of what Gould et al. (1996) call the "transnational treadmill of production." Implementation of these proposals appears unrealistic given the structural constraints posed by the current world-system.

What is being done to challenge the world-system? Several organizational and political changes are currently underway. Non-governmental organizations (NGOs)[37] have pressured the Mexican state to develop and enforce higher standards, train public health and *maquila* workers, and open the policy discourse to the public about the prevalence and use of toxic materials.[38] NGOs such as the Coalition for Justice in the Maquiladoras, the Maquila Solidarity Network, the Maquiladora Health and Safety Network, and the Southwest Network for Economic and Environmental Justice have begun to monitor and study actual conditions in and around the *maquiladoras*, as well as pressure TNCs to change operating procedures. These and other NGOs have been successful in their efforts (Bacon 2001; Keck and Sikkink 1998; Roberts 1998). Williams (1999: 150–152), for instance, presents compelling evidence that the Coalition for Justice in the Maquiladoras[39] cross-border collaboration campaigns were successful in

36. See, e.g., Chomsky (1999), Chossudovsky (1997), Clapp (1998a:103–104, 2001: chapters 6 and 7), Gould et al. (1996:chapter 5), McMichael (2000), Sanchez (2002:1382, 1385–1389), and Tilly (1995).

37. A special type of what Arrighi, Hopkins, and Wallerstein (1987) and Wallerstein (2002) refer to as anti-systemic movements.

38. See, e.g., Bacon (2001), Levy (1995:80–82), Merideth and Brolin (1995), and Zabin (1997).

38. Hogenboom (1996), Pena (1997:304ff), and Williams (1999), among others, discuss environmental NGO activity on both sides of the border. NGOs have become important actors on the world stage (Boli and Thomas 1997; Keck and Sikkink 1998; Simmons 1998; Smith et al. 1997; Williams 1999). In fact, Boli and Thomas (1997:187) argue that international NGOs form an emerging global proto-state. And several pundits in the post-Seattle period have referred to "NGO swarms" attacking TNCs (The Economist 1999).

39. This is a coalition of groups and individuals from Canada, Mexico, and the United States that has pursued *maquiladora* industries engaged in illegal and "errant" labor and environmental practices. The coalition consists of unions, human rights activists, environmentalists, religious groups, and public health interests. It has used a variety of tactics, including lobbying and testifying before various legislative and administrative

achieving goals.[40] And, more recently, a coalition of Canadian, U.S., and Mexican NGOs was successful in expanding right-to-know legislation in Mexico, including the establishment of a Pollutant Release and Transfer Register that is similar to those in Canada and the U.S. (Nauman 2003).

Economic globalization and the attendant adverse consequences have clearly fostered counter-hegemonic forces or anti-systemic movements in the form of transnational networks of NGOs. The extent to which NGOs will actually curb the adverse consequences of economic globalization in Mexico and elsewhere is the subject of debate (see, e.g., Moghadam 1999; Mol 2001; Sanchez 2002, Wallerstein 2002; Wilkin 2000). Peter Evans's (2000:240)[41] comment of several years ago is particularly apt:

> Is it possible that a ragtag set of activists who have managed to turn fax machines, Internet hook-ups, and some unlikely long-distance personal ties into a machinery for harassing transnational corporations and repressive local politicians might foreshadow a political process that could reconfigure the rules of the global political economy so as to foster equity, well-being, and dignity? It may be utopian to contemplate such a possibility, but it is certainly foolish not to take the elements of counter-hegemonic globalization that are already in place and push them as far as they can go.

Counter-hegemonic globalization in the form of transnational networks of NGOs may seem even more utopian in the context of 2003, but it remains one of

bodies, letter writing, picketing and demonstrations, and organizing stockholders of companies operating in Northern Mexico (see, e.g., Bacon 2001; Williams 1999). See also Dreiling (1998).

40. As Keck and Sikkink (1998:200) note:

> Transnational value-based advocacy networks are particularly useful where one state is relatively immune to direct local pressure and linked activists elsewhere have better access to their own governments or to international organizations. Linking local activists with media and activists abroad can then create a characteristic 'boomerang' effect, which curves around local state indifference and repression to put foreign pressure on local policy elites. Activists may shop the entire global scene for the best venues to present their issues, and seek points of leverage at which to apply pressure. Thus international contacts amplify voices to which domestic governments are deaf, while the local work of large country activists legitimizes efforts of activists abroad.

41. Evans is calling for what Karliner (1997) has dubbed "grassroots globalization." Sklair (1998:298–305) refers to this as "disrupting" the global capitalist system at the local level (by "disrupting the TNCs," "disrupting the transnational capitalist class," and "disrupting consumption"), but coordinating such disruptions globally. Others use terms such as the development of "civil society" (Lofstedt and Sjostedt (2001) or "global civil society" (Carruthers 1996; Lipschutz 1992), "post-national communities" (Beck 1999:16), and "globalization from below" (Brecher, Costello, and Smith 2001).

the most viable means for curbing the adverse consequences associated with hazardous facilities in the EPZs of the periphery. Stopping the core's appropriation of carrying capacity is another matter, for that is embedded in the very structure of the current world-system.

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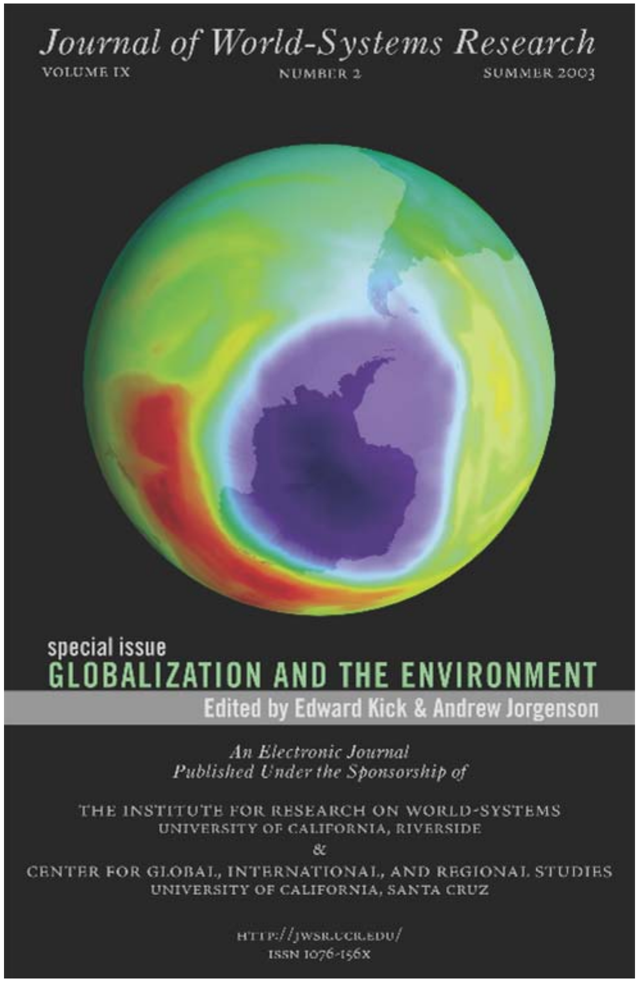

ABSTRACT

Building on prior work in world-system analysis and human ecology, we test a macro-level theory that social and demographic causes of deforestation will vary across zones of the modern world-system. Using multivariate regression analysis, we examine models of deforestation over the period 1990-2000. We test for main effects of world-system position, two different population variables (urbanization and proportion under working age), and economic development within zone, as well as for the contextual effects of these variables as they operate differently across world-system positions. Our findings indicate that generic models of deforestation need to be qualified, because the particular social factors most closely associated with deforestation tend to vary by position in the global hierarchy. Deforestation at the macro level is best explained by considering effects of socio-demographic processes contextually, in terms of world-system dynamics. We discuss the findings in a more general world-systems and behavioral ecological framework, and suggest the field will be well served with more precise theorizing and closer attention to scope conditions.

Theorizing and Rethinking Linkages Between the Natural Environment and the Modern World-System: Deforestation in the Late 20th Century*

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INTRODUCTION

In tracing world ecological degradation over a period of five millennia, Sing Chew (2001) points out that "...the history of civilizations...and states is also the history of ecological degradation and crisis...[as such]...ecological relation is as primary as the economic relation in the self-expansionary processes of societal systems..." (pp. 1–2). Particularly over the last half of the twentieth century with its expanding global markets, there has been a dramatic upsurge in the rate at which deforestation is occurring (Chew 2001:141 ff.; also see Noble and Dirzo 1997).

While deforestation is a worldwide problem, prior research indicates that the rate of deforestation, as well as its causes, tends to vary markedly by a country's position in the world-system (Burns et al. 1994; Kick et al. 1996). Thus, while the history of the modern world is replete with illustrations of the ecologically destructive nature of geographic expansion of the system (Moore 2000; Smith

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1994; Tarr 1991), it is important to note that where a nation stands in the modern global hierarchy, and the national characteristics stemming from it, influence the proximal causes, amounts and types of environmental degradation it experiences (Colinvaux 1980; Ponting 1991).

In an increasingly globalized world economy, national inequalities continue to manifest themselves in a stark fashion. Wallerstein (1974, 1979, 1984, 2003) has argued that the current capitalist world-economy or world-system, which emerged in the 16th Century and continues to evolve, is characterized by a global division of labor, as well as exploitation and unequal exchange that has generated and maintained a relative structural inequality across core, semiperipheral and peripheral "zones" of the world-economy.

This general view has been expanded upon extensively, and we do not replicate that discussion here. Rather, we refer the reader to a number of works elaborating this perspective (Chase-Dunn 1998; Chase-Dunn and Hall 1997b; So 1990; Frank 1979 & 1980; Kentor 2000; Snyder and Kick 1979; Kick et al. 1995 & 1998; Bollen 1983; Modelski and Thompson 1996; Terlouw 1993). Researchers have empirically examined the impacts of these unequal global relationships on various national level outcomes. Examples of these, among many others, include economic growth (Chase-Dunn 1975, Bornschier and Chase-Dunn 1985, Rubinson and Holtzman 1981, Kentor 1998; Kentor and Boswell 2003), and urbanization (Timberlake and Kentor 1983; Kentor 1981; Smith 1996, 2003, London and Smith 1988, Taylor 2003).

Within the past decade, there also has been a growing interest in attempting to understand environmental problems in a world-system framework. A number of cross-national studies have been done from the world-system perspective that shed light on problems such as greenhouse gas emissions (Roberts and Grimes 1997, 1999, 2002; Burns et al. 1997, 2001); international patterns of accumulation and transfer of hazardous waste (Frey 1995, 1998, 2002); the ecological footprint (Jorgenson 2003; also see Jorgenson and Burns 2003; York, Rosa and Dietz 2003); as well as studies of deforestation (Burns et al. 1994, 1998; Kick et al. 1996; for earlier case studies see Bunker 1984, 1985). In this study, we build on and expand prior work, in order to understand more clearly the worldwide problem of deforestation, particularly as it has taken place in the modern era.

THE WORLD-SYSTEM AND ENVIRONMENTAL CONSEQUENCES

We examine relationships between the world-system position of nations, their national attributes and their consequent environmental profiles. We theorize that due to world-system impacts, national deforestation rates will vary cross-nationally in systematic ways. While these impacts are witnessed directly, they also are manifested indirectly via national institutions, and demographic as well as geographic dynamics. The causal forces we specify culminate in interpretably different deforestation consequences for core, semicore, semiperiphery and periphery nations. Our specification is informed by a range of case studies (e.g. Bunker 1984, 1985), and quantitative cross-national efforts (e.g. Burns et al. 1994, 1997, 1998, 2003; Kick et al. 1995, 1996; Rudel 1989; Roberts and Grimes 1997; Ehrhardt-Martinez 1998, 1999; Ehrhardt-Martinez et al. 2002), that *when taken together* permit the formation of a more coherent approach to the linkages among international dynamics, national properties, and deforestation consequences.

Our theoretical formulations and analyses respond in part to prior work in the area that does not consider the full range of world-system or dependency processes. Ehrhardt-Martinez (1998, 1999), for example, sees a theoretical vacuum in this area. While her work does include a world-system/dependency variable, it does not adequately test for a range of world-system dynamics, despite evidence from prior work (e.g. Kick et al. 1996) that these dynamics, including *interactions* between the world-system and domestic processes, have significant power in explaining national variation in environmental degradation—particularly deforestation.

An additional and related limitation of much of the work in this area is the examination of forest change in developing societies only (see Ehrhardt-Martinez 1998, 1999; Allen and Barnes 1985; Rudel 1989; Rudel and Roper 1997). While developing societies clearly are crucial areas of concern, it is also important to consider the fragile nature of boreal forests, and the state of temperate forests (Chew 2001:150 ff.), many if not most of which are in what could be considered core or semicore countries. Additionally, a number of macro-level social processes are likely to emerge from empirical cross-national research only when considering the world as a whole, rather than limiting the focus to one part of it (see Tilly 1984).

Due to their respective positions in the world-system, core countries tend to be the most technologically and economically advanced in the world. Also, because of natural geographic as well as the economic and political advantages stemming from their relative position in the global hierarchy, huge amounts of resources are available to countries of the core (Fain et al. 1996/1997; Lenski and Nolan 1984). These dynamics are no small consideration when analyzing changes in the world's forest cover. It bears noting that about half of the world's forests are located in industrialized countries of the core or the semicore (WRI 1994: 135). When the technology and wealth of core countries are coupled with their abundant forests, a far greater physical opportunity to deforest and to *re*forest is provided than for the other zones (Burns et al. 1994; also see Rudel 1998). Thus, the increased efficiencies of core production, and alternative resources available to them, may in some cases help to facilitate favorable forestation consequences there.

Further, as prior work on the world wood trade indicates, at least some of the deforestation in the periphery and especially in the semiperiphery, is attributable to world system dynamics that favor core or semicore countries (Kick et al. 1996). One of the primary stimuli to industrializing economies is their export market. The natural and animal resources of the non-core, such as forests and cattle, represent such prime commodities for export. One would expect such exports to generate deforestation in semicore and semiperipheral countries, just as they do in the periphery[1] (Lang 2002; Behrens 1994; Sierra and Stallings 1998).

The industrializing countries of the semicore and semiperiphery are potentially upwardly mobile in the world system (So 1990; Wallerstein 1979; Arrighi and Drangel 1986; Terlouw 1993; Burns et al. 1997), and as a result, are in many respects undergoing more rapid change than either peripheral or core nations. Prior research has suggested that the dynamics of this process, particularly economic growth, expands the availability of capital for a range of activities that can exploit domestic resources (Rudel 1989).

A series of findings from prior work in fact indicate that in terms of at least some outcomes and at some time periods, environmental degradation is most severe in the industrializing countries of the semiperiphery (Burns et al. 1994; Kick et al. 1996; Roberts and Grimes 1997) or the semicore (Burns et al. 1997)– that is, in the middle ranges of the world-system hierarchy rather than at either the high or low end. This has led some researchers to refer to an environmental "Kuznets" effect (c.f. Kuznets 1955), in which there is a non-linear relationship between development variables such as urbanization or economic growth, and environmental degradation (e.g. Burns et al. 1994, 1997, 1998; Bergesen and Bartley 2000; Kick et al. 1996; Roberts and Grimes 1997; Ehrhardt-Martinez 1998, 1999; Ehrhardt-Martinez et al. 2002; York, Rosa and Dietz 2003).

Yet it is important to point out that some dynamics may follow a linear relationship while others may not. For example, Burns et al. (1997) in a study linking greenhouse gas emissions with world-system processes, found that position in the world-system hierarchy was linearly related with national emissions of one

1. As a number of researchers have pointed out (e.g. Guess 1979, 1991; Hecht 1985), much of the deforestation in developing countries is attributable to land-clearing for the purpose of livestock ranching. Much of the meat from the eventual slaughter of the livestock is then exported to more developed countries.

greenhouse gas (CO_2), while emissions of another greenhouse gas (methane) tended to be heaviest in semicore countries.

Prior work on deforestation (Burns et al. 1994) finds that for the period from 1965 to circa 1990, deforestation was indeed more severe in the semiperiphery than in either the periphery or the core. This effect, at least in terms of forest change dynamics, may be attributable in part to reforestation programs in the core and, to a lesser extent, in parts of the semicore.

It is worth considering that the lower rates of deforestation in the periphery than in the semiperiphery may have been an historical artifact. Peripheral countries continue to experience the greatest population growth, which puts a strain on resources of all sorts. Further, while peripheral countries are the least urbanized, many of them are urbanizing rapidly, as they are increasingly drawn into the dynamics of the world system.

Yet the semiperiphery has been in a trajectory of urbanization longer than has the periphery. In fact, much of the urbanization of the semiperiphery is likely connected with the increasing incorporation into the world-system and its export-based economies. Also, the increasing consumption associated with the modernization process is likely to be catalyzed by urbanization there.

Ironically, the overdevelopment of urban areas and the social dislocation associated with it, often precipitates encroachment into forested regions (see Burns et al. 1994; Postel and Ryan 1991; Anderson 1990). This "rural encroachment" (Burns et al. 1994), coupled with other in-migration patterns, such as refugee migration (Homer-Dixon 1994, 1999; Guess 1979; Schmink and Wood 1992) often results in forested regions' eventual "development" into agricultural or even industrial usage (Koop and Tole 1997; Rudel 1998 & 1989). Some developing countries have even instituted policies promoting migration to such areas (Miller et al. 1991; Guess 1991) (e.g. to foster national defense goals, despite the fact that development in forested areas for agricultural or other uses has been directly linked to environmental degradation in general, and deforestation in particular) (Anderson 1990; Nazmi 1991). A vast proportion of out-migrants from urban to rural areas in the periphery of the world-system additionally tend to be relatively poor, unskilled and undereducated, and thus have little to hold them in the cities. This combination has been shown to be associated with a number of aspects of environmental degradation (Ghimire 1994; Niang 1990).

Perhaps more alarming is recent work that has begun to describe a process in which technological diffusion leads to increasing "efficiencies" of logging and other deforesting practices. An increasing worldwide awareness of an impending shortage of forest products may tend to increase demand for wood from any source. These are accompanied by other shifting constraints in the world economy such as lowered shipping and transportation costs, as worldwide exchange practices move increasingly in the direction of "free trade" particularly the variety championed by the World Trade Organization (e.g. Fink et al. 2002; also see Cukrowski and Fischer 2000; Leonard 1988). The widening gap in environmental regulation between the consuming countries of the core and the lack of it, particularly in the periphery, shifts capital's cost/benefit ratio in the direction of a number of environmentally devastating practices toward the periphery (e.g. Xing and Colstad 2002; Mitchell and Cutter 1997; Bello 1992). There is, moreover, a continuing tendency to externalize environmental costs (e.g. Steininger 2001).

The changing face of the logging industry is worth noting as well. It is becoming increasingly common for a company based in, for example, a semiperipheral country such as Indonesia, to sponsor logging efforts in other semiperipheral or peripheral countries. The combination of aforementioned factors may make it "cost effective" for the exploitation of resources from a South Asian or perhaps East African country.

For lack of a better term, we might refer to this pattern as "recursive exploitation," in which a nation in the semicore or semiperiphery is at a disadvantage to one in the core, yet is able to work exchanges in its favor when they involve the semiperiphery or periphery. This would include practices such as those we have just described, in which, for example, a semiperiphery-based company extracts resources from a weaker country in the same tier, or a lower tier, than itself. While historically there has been somewhat of a "regional bias" in international trade (Ludema 2002), what could be considered a region may itself be enlarging with increasing economies of scale, decreasing shipping costs and favorable trade conditions (Jovanovic 2003).

Thus, changing (and in many ways worsening) worldwide economic conditions and external capital investments may drive significant cutting of peripheral forests (Ambrose-Oji et al. 2002). While the magnitude of deforestation in the periphery has been relatively restricted by marginal technological development and somewhat circumscribed international trade linkages in the past (see Kick et al. 1996), the shifting balance may well be in the direction of even greater and more efficient exploitation of the natural resources of the periphery.

In addition to world-system processes, it is important to consider other explanatory variables that theorization and empirical research have indicated are key causal agents in deforestation. We consider particularly the effects of population and affluence within the context of human ecological theory. We then turn to questions about whether these factors are likely to *interact* with world-system processes, and what those interactions mean in terms of ecological degradation in general and deforestation in particular.

POPULATION DYNAMICS AND RELATIVE AFFLUENCE IN THE WORLD-SYSTEM

As Malthus (1798/1960) pointed out over two centuries ago, population is an important factor in the long-term survival of the planet (for more recent statements in this tradition, see Ehrlich 1968; Ehrlich and Ehrlich 1990, 1991; also see Cohen 1995). Increasing numbers of people using resources tend to have a cumulative impact on the environment (Hunter 2000; Preston 1996; WRI 2000). But even in this case, the human organizational environment of that population often makes a profound difference.

A commonly utilized theoretical framework consequently posits that population (P) interacts with affluence (A) and technology (T) to produce environmental impact (I) (Commoner 1972, 1992, 1994; Commoner, Corr and Stamler 1971; Ehrlich and Holdren 1970, 1971, 1972; Dietz and Rosa 1994; York, Rosa and Dietz 2002, 2003). As the "IPAT" model implicitly acknowledges, taking population in isolation misses the dynamics of the causes of environmental degradation, because the strain on resources varies so widely from one unit of population to another (for a detailed theoretical discussion see Dietz and Rosa 1994; also see Cohen 1995).

In our theorization, we draw on the IPAT model (and its "STIRPAT" variant used with stochastic regression models) (see Dietz and Rosa 1994; York, Rosa and Dietz 2003). Recent research in this framework finds that just two variables—(P)opulation of working-age adults, and (A)ffluence as measured in terms of GDP per capita—explain approximately 95% of the variance in a nation's macro-level consumption as measured by the "ecological footprint"[2]

[2] More specifically, the ecological footprint accounts for the consumption process itself, including forest resources (for discussions, see York, Rosa and Dietz 2003; Jorgenson 2003; Jorgenson and Burns 2003; Wackernagel et al. 2000; Wackernagel and Silverstein 2000; also see Bernstam 1990).

While it is difficult to know this definitively, it would appear that the micro- and meso-level causes of deforestation are likely to vary by world-system position also. For example, the periphery may have more slash-and-burn activity while in the semiperiphery (and perhaps the semicore), there may be more logging for commercial export (Kick et al. 1996). Gutelman (1989) estimates that slash-and-burn horticulture accounts for 70% of Africa's, 50 % of Asia's, and 35% of Latin America's deforestation. Differences among zones in the world-system appear to be seen as in terms of how environmental movement organizations and "greening" policies play themselves out as well. For discussions of international differences in approaches to environmental attitudes and discourse, see Dietz and Kalof (1992); also see Burns and LeMoyne (2001); and Perz (2002). The

(York, Rosa and Dietz 2003).[3] Those variables are robust across models controlling for alternative explanations from a wide array of theories, including political-economic, modernization, and human ecological perspectives (York, Rosa and Dietz 2003; also see Jorgenson 2003; for a detailed explanation of the rationale and measurement of the footprint itself, see Wackernagel et al. 2000, Wackernagel and Silverstein 2000; Wackernagel and Rees 1996).

Yet population *per se* does not explain a great deal about environmental degradation. Prescinding momentarily from the question of population's interaction with other IPAT variables (most notably, measures of affluence), we are still left with the question of what *aspect(s)* of population are most closely associated with environmental depletion. As prior work testing those ideas specifically has begun to show, *distributions* of the population (particularly in terms of age and geography) make profound differences in amounts and specific manifestations of environmental degradation (Burns et al. 1998). When we do put this together with other factors, the level and allocation of resource usage is largely a function of living standard, which in turn is associated with other factors such as levels, distributions and uses of technology in the society.

Consider, for example, a number of studies indicating that the usage of resources in cities is quite different from resource usage in rural areas (Smith 1994, 1996; also see Kasarda and Crenshaw 1991; Crenshaw and Jenkins 1996). As nation-states are incorporated into the world economy, they tend to have concomitant rises in urban populations (Smith 1996, 2003; Kentor 1981; Timberlake and Kentor 1983). Largely because international trade tends to take place through urban areas, this further draws urbanizing nation-states into the world-system (Taylor 2003), and so this cycle is self-reinforcing.

broader point is that the causes, types and degrees of environmental problems differ dramatically in terms of where a country stands in the internationally hierarchy, as do ways in which people there think and communicate about them.

3. York, Rosa and Dietz (2003) do control for a non-linear (in this case, quadratic) effect of GDP per capita. Each of the other control variables is modeled only linearly. As in the case of Ehrhardt-Martinez (1998, 1999; Ehrhardt-Martinez et al. 2002) modeling social and demographic causes of deforestation, York et al. only model world-system position as a main effect. Yet as prior research on deforestation and other types of environmental degradation has shown both theoretically and substantively, world-system dynamics tend to have indirect and interactive effects (Burns et al. 1994, 1998, 2003; Kick et al. 1996).

Dramatic increases in urban populations put strains on resources as well, in that this giving rise to a "metabolic rift" in consumption patterns between urban and rural areas (Jorgenson 2003; Jorgenson and Burns 2003; Foster 1997, 1999, 2002; for case studies in Latin America see Stonich 1992, Mueller 1995, also see Bunker 1984 & 1985). As this occurs, large urban agglomerations put demand on resources for their own use and for export, while extraction of those resources tends to be from rural areas where there are still natural resources available (Meardon 2001; also see Smith 1994, 1996).

Significant amounts of deforestation are attributable to international trade in wood and wood products, although the specific ways in which a country experiences these dynamics are different depending upon its position in the world-system (Kick et al. 1996). This is part of a more general process in which the ability to garner resources in an unequal exchange varies with a society's position in the world economy (Amin 1974, 1976; Hornborg 1998, 2000; also see Alderson and Nielsen 1999; Landsberg 1979; London and Smith 1988; Modelski and Thompson 1996; O'Connor 1989; Podobnik 2002). This in turn likely has a profound effect upon its ability to consume resources from less affluent parts of the world while strengthening the chances of conserving its own resources.

Questions about age cohorts are crucial as well. Ecologists (e.g. Catton 1980, 1994; Fearnside 1984, 2000; Postel 1994) often refer to the *carrying capacity* of the natural environment. In analyzing plant or animal populations, carrying capacity is the number of a given species able to live indefinitely within its natural environment, given constraints on resources such as food and shelter. While a given population may live beyond its carrying capacity (sometimes referred to as "overshoot") for a relatively short period of time, it cannot do so indefinitely. That period tends to correspond closely with the reproductive time lag of the species in question, because the greatest strain on resources occurs when coming into adulthood (c.f. Pimentel et al. 1994). The consequences for the human species of these two aspects of behavioral ecological theory considered together—the potential for overshoot in conjunction with the reproductive time lag effect—are considerable: (1) the effects of overpopulation may not be fully experienced until some *significant time after* onset; and (2) the potential for ecological degradation is *not* spread evenly. *Ceteris paribus*, adults tend to put more strain on resources while children put relatively less strain on them–until they themselves come into reproductive age. In this paper, we specifically examine the relationship between the below-working age cohort and national change in forest cover. It bears remembering that *in the short run* corresponding to the period we test here, this is expected to be the *least* impactful of the cohorts.

THEORETICAL SUMMARY

We explore a number of alternative conceptions of the constructs in the impact model. The permutations we develop are driven by different demographic and social dynamics, examined both linearly and interactively with world-system processes. In particular, we pay close attention to the question of *what about* population is impactful. To inform our analysis, we borrow several ideas from behavioral ecology, demography and macro-sociology, but which could bear further development in the environmental sociology literature.[4]

In summary, then, we expect the particular social factors most closely associated with deforestation will tend to vary by world-system position. We also theorize about population dynamics, particularly in terms of the relative *distribution*s between urban and non-urban areas, and between working-age and below-working age people. We expect that with increasing urbanization, resource depletion *per unit of population* increases as well; consistent with our earlier theorization, we also expect the effects of urbanization will vary across world-system position. Likewise, we expect that effects of population age cohorts will also vary by zone in the world-system.

METHODOLOGY

Country Sample

Following conventional practices in this research area, our sample includes all countries of the world for which data were available on all independent and dependent variables modeled. Preliminary regression analyses showed Oman was a statistical outlier, based on its standardized residual (> 8.0), the Mahalanobis distance score (largest relative value), and its Cook's D value (> 4.0). With the omission of Oman the sample is comprised of 73 nations (for in-depth discussion of effects of influential outliers, see Bollen and Jackman 1985). The final sample includes 10 core, 11 semicore, 36 semiperipheral, and 16 peripheral countries.

4. While world-system analysis is central to the framework of our study, we recognize the importance of related works on the environment in other scientific fields (e.g. Pimentel et al. 1994; Ricklefs 1973; Colinvaux 1980; Nilsson and Shivdenko 1997; Hinde 1974; Miller 1969; Gause 1934; Grossman and Krueger 1995; Beckerman 1992; Noble and Dirzo 1997; Fleming 1996; Allen and Barnes 1985; Behrens et al. 1994). Researchers seeking to understand the complexities of these processes would do well to incorporate at least some of these literatures into their theorization.

We identify the structural position of countries in the world system using Kick's classification (1987; also see Snyder and Kick 1979). Detailed discussions of alternative operationalizations of the world system appear elsewhere and we do not attempt to recreate those discussions here (see Burns et al. 1997, or Kentor 2000 for summaries of the strengths and weaknesses of alternative schemas). Appendix A reproduces this classification for countries used in our analyses.

Outcome Variable

Our forestation measure is the average annual percentage change in forest cover over the 1990–2000 period, based on FAO measures (World Bank 2002–see Appendix A). Data coverage is more expansive for this period compared to earlier years, and we presume companion improvements in data quality. Percentage change scores in forest cover tend to be less skewed, and therefore offer some methodological advantages relative to the use of raw change measures (Ehrhardt-Martinez 1998), but ultimately our choice of this measure rests on its validity relative to our theorization. For ease in interpretation of our results we emphasize that our variable is annual percentage change in forest cover. Thus, *de*forestation would be a change in a negative direction, while a positive number represents forestation.

Predictor Variables

As control variables, we include forested land as a percentage of total area of a country circa 1990, and a dummy variable for countries with less than 4% of land that is forested (World Bank 2002—see Appendix A). When taken together, these measures adjust for "starting points," including the relatively more unique processes of forestation in largely desert environments.

We also include a modified world-system classification measure, an eleven-category ordinal variable, as a control variable in our regression estimations (Kick 1987). This variable distinguishes the more and less central (i.e., powerful) nations in the world system. In using a generic measure such as this one, we address a range of world-system processes, which are treated individually in other studies (e.g., debt dependency—see Ehrhardt-Martinez 1998).

To test the postulated effects of the processes theorized above, we include three substantive regressors, each measured as an average annual percentage change score. These include average annual change in urban population 1970–90 (P), average annual change in gross domestic product per capita based on purchasing power parity figures for 1975–90 (A) and average annual change in radios per capita, 1970–90 (T). Also, we include another theorized population dynamic, the average annual change in the proportion of the population under age 14 (P) (World Bank 2002).

We calculate descriptive statistics. The means and standard deviations for our variables, along with the zero-order correlations among them, are reported in Appendix B.

Most cross national research endeavors model main effects only, but we proceed to examine the possible lack of homogeneity of slopes among four tiers of the world system (i.e., core, semicore, semiperiphery, periphery; see Appendix A for a listing of countries in each tier) for three of our substantive regressors. In order to test this assumption, we create (k–1=3) slope-dummy variables following Hamilton (1992:88–92). A slope-dummy variable is a form of interaction term created by multiplying a continuous measurement variable (i.e., x_1=Urban Population) by a dichotomous dummy variable (i.e., x_2=Core), which creates a new variable (i.e., Urban Population x Core = x_1x_2). This newly constructed variable x_1x_2 has the values of x_1 for all cases for which the dummy variable was "1" and zeros for all the remaining cases.

The test for homogeneity of slopes consists of entering into a regression model the original main effect (e.g., percent change in urban population), and the k–1 or three slope-dummy variables created from this main effect via the process documented above. A significant coefficient for any of the three slope-dummy variables indicates that the slope for this group/category differs significantly from the excluded group/category.

In order to measure the couplings of national position in the global system to the substantive regressors in a fully specified model that includes important controls, we extend our construction of slope-dummy variables to include all four world-system tiers. We use these four "contextual" or "coupling" variables to demonstrate the different effects of each of the three substantive measures in the context of a fully specified and controlled model. Thus, four independent variables are created, as the original measurement variable is split into four separate regressors.

A finding of "statistical significance" for a specific slope-dummy simply indicates how (un)likely it would be to obtain a coefficient of that magnitude by chance. It does not indicate that the slopes for, say, the semiperiphery and periphery, for the given measurement variable (e.g., urban change) are statistically different as is the case in the technique outlined above (Hamilton 1992). Additionally, the standardized regression coefficients associated with these slope-dummy variables indicate the relative contribution of the independent variable within that tier (e.g., semiperiphery or periphery) to explaining variation in the dependent variable, while simultaneously controlling for the other independent variables included in the model.

We believe this produces a far more appropriate wedding of theory and measurement for world-system theory, since our framework emphasizes the coupling of analytical domains (rather than merely their generic main effects). We also are interested in the relative effects of the couplings for core, semicore, semiperipheral and peripheral countries compared to one another. Further, we cannot in this case justify theoretically the assumption of "multiplicative effects" associated with traditional, multiplicative interaction terms of two continuous variables.

Model Estimation Procedures

Almost all published quantitative cross-national research such as ours has relied upon ordinary least squares (OLS) regression techniques and we use OLS herein. We verified that the coefficient and standard error estimates from our OLS results were robust by comparing them with findings generated through bootstrap analyses (available from the authors upon request).

We also investigated the potential severity of multicollinearity, following the reasoning of Belsley et al. (1980). An examination of bivariate correlations among all independent variables, and a comparison of standardized regression coefficients (in terms of magnitude and direction) with the bivarite correlation between each regressor and the dependent variable, showed no evidence of estimation difficulties due to multicollinearity. As well, our examination of the matrix of correlations among the regression coefficients themselves reinforced the conclusion that there were no discernable estimation problems caused by multicollinearity. We note, however, that multicollinearity difficulties did surface when we utilized an interaction model technique (Hamilton 1992) to test for homogeneity of the slopes between tiers of the world system, which is typical of many interaction model estimations. We present these findings subsequently.

RESULTS AND DISCUSSION

As noted, we test our hypotheses using a series of multiple regression models. In the first such model, we test only for main effects of the population, affluence and technology variables on deforestation, with controls for forest cover in 1990, world-system position and small forest area. The results are summarized in Table 1.

We find a strong main effect for world-system position—with increasing dependency in the world-system there are significantly higher levels of deforestation. The highest rates of deforestation are in the periphery. This does not imply that evironmental degradation necessarily has alleviated much in the semiperiphery—rather, it is attributable to deforestation in the periphery having gotten more intense in recent years[5].

In addition to the relatively large effect for world-system position, the greater the level of increasing affluence (as reflected in GDP per capita), the less the

Table 1 – Main Effects Model for Average Annual Change in % Forect Cover (1990–2000)

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	0.560	0.577		0.972	0.335	
% Forest cover in 1990	0.003	0.007	0.035	0.348	0.729	–0.161
World-System Position	–0.168	0.061	–0.332	–2.737	0.008	–0.485
Dummy (1 = less than 4% forest cover)	1.698	0.519	0.336	3.272	0.002	0.420
% Urban Population	–0.261	0.106	–0.295	–2.450	0.017	–0.458
Proportion under age 14	0.690	0.332	0.283	2.076	0.042	–0.317
Gross Domestic Product "PPP"	0.090	0.032	0.319	2.825	0.006	0.362
Radios per 1,000	–0.019	0.012	–0.161	–1.557	0.124	–0.387
R–square = .520						

negative environmental outcome in terms of deforestation. In order to control for the relatively low inertia in those countries with small amounts of forest, we added a variable for countries with low levels of initial forest cover, and not surprisingly, this measure turns out to be significantly, positively related to forestation. This simply underscores the fact that all else held equal, countries with small amounts of initial natural forest resources find it relatively easy to obtain high forestation rates with only small absolute changes.

[5] In comparing our findings with those studies from earlier periods, we are struck by how much of the negative change over the last decade is located in the periphery. For example, Burns et al. (1994) found that for a period beginning in 1965 and ending circa 1990, the average annual percent change in forested land was: core = 0.11, semiperiphery = –0.99, and periphery = –0.18. (We note here that since Burns et al 1994. had a more traditional core/semiperiphery/periphery trichotomy, in contrast to our four-category scheme, their results are not directly comparable. However, even after taking into account the different operationalization schemes, the period differences are remarkable.) In the current study with average annual percent change in forested land as the dependent variable, the mean values from our sample are: core = 0.24, semicore = 1.11, semiperiphery = –0.54, and periphery = –1.55. Thus, while in the previous study, the deforestation rate was about five times greater in the semiperiphery than in the periphery, that ratio has changed dramatically. The data used in this study indicate that in the period 1990–2000, the periphery is deforesting at a rate almost 3 times that of the semiperiphery.

More broadly, the progressively greater deforestation among nations lower in the world-system hierarchy appears in significant part to be attributable to the unequal exchange and consumption patterns that play themselves out in international exchanges. Consider, for example, that the *more* resources per capita a country consumes (as operationalized by its ecological footprint), the *lower* the level of deforestation it tends to have (Jorgenson 2003; Jorgenson and Burns 2003).

With only one exception, each of the regression coefficients has a sign that matches its zero-order correlation with the dependent variable. The one exception is population under age 14, which goes from a significantly ($p<.05$) negative zero-order relationship ($r = -.317$) to a significantly positive standardized regression coefficient (beta weight = .283), when the model has the full complement of control variables. This is an interesting but not totally unexpected finding.

In making sense of this, it bears remembering that while population in general puts a strain on resources, the strain is *not* uniform across age cohorts. Prior research has found working-age population to be highly predictive of deforestation (Burns et al. 1998) and the ecological footprint (York, Rosa and Dietz 2003), and that relationship remains robust even in models controlling for a number of other factors (including other demographic and human ecological variables). These prior findings are consistent with behavioral ecological theory and research, which suggest that adults in a wide array of species tend to put a greater strain on resources than do younger cohorts. In our fully controlled main effects model, the other variables (particularly, and not surprisingly, the urbanization variable) capture much of the negative covariance between a young population structure and forest cover. While fertility rates for women of childbearing age are higher in rural areas, the preponderance of young working-age adults in urban areas leads to the greatest growth there.

It is also worth considering that as this younger cohort ages, it will likely put increasingly greater strain on a number of resources (including, but not limited to, forests and their products) as the next generation competes to find niches for itself. Coupling this with the well-known structure of population pyramids in less-developed countries, we are led to consider the real possibility that in a species with as long a reproductive time lag as humans, the strain on resources, including forests, will very likely increase over the next two decades—and this will be the case even in the highly unlikely scenario of overall population remaining stable over that period.

We next turn attention to the contextual (i.e., zone-specific) effects of our

Table 2 – World-System Position by Urban Population Interactions

Table 2a. Test of Different Slopes for Percent Urban Population with Semi-Core the Excluded Category

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	–0.032	0.248		–0.129	0.898	
% Urban Population Main Effect	0.793	0.500	0.900	1.585	0.118	–0.458
% Urban Population Core	–0.004	1.425	0.000	–0.003	0.998	0.143
% Urban Population SemiPeriphery	–1.000	0.480	–0.802	–2.084	0.041	–0.075
% Urban Population Periphery	–1.213	0.485	–1.381	–2.499	0.015	–0.464
R-square = .289						

Table 2b. Contextual 4-Dummy Model for Percent Urban Population

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	0.283	0.705		0.401	0.690	
% Forest cover in 1990	0.000	0.008	–0.004	–0.039	0.969	–0.161
World-System Position	–0.122	0.084	–0.241	–1.453	0.151	–0.485
Dummy (1=less than 4% forest cover)	1.613	0.533	0.319	3.028	0.004	0.420
Proportion under age 14	0.655	0.343	0.268	1.911	0.061	–0.317
Gross Domestic Product "PPP"	0.089	0.032	0.315	2.746	0.008	0.362
Radios per 1,000	–0.017	0.012	–0.145	–1.391	0.169	–0.387
% Urban Population "Core"	–0.078	1.580	–0.006	–0.049	0.961	0.143
% Urban Population "SemiCore"	0.407	0.489	0.088	0.832	0.409	0.268
% Urban Population "SemiPeriphery"	–0.231	0.130	–0.185	–1.771	0.081	–0.075
% Urban Population "Periphery"	–0.310	0.125	–0.353	–2.480	0.016	–0.464
R-square = .538						

regressors. For subsequent regression runs, as described above, we collapse the 11-position world-system variable into the four zones (core, semicore, semiperiphery, and periphery—see Kick 1987). We use slope-dummy variables created for these zones to assess homogeneity of slopes among zones in a restricted interaction model (reported in Tables 2a, 3a, and 4a, respectively), and slope dummy contextual effects in a fully controlled model (reported in Tables 2b, 3b, and 4b, respectively). In this manner, we serially model world-system specific effects, as they vary in context between core, semicore, semiperiphery and periphery nations.

To test for homogeneity of slopes across world-system positions for % urban population, we run a classical main effects model (Hamilton 1992), along with

its interaction with three of the world-system zones. The slopes for three zones are tested against the excluded category, in this case the semicore. This model is shown in Table 2a. The significant coefficients for the semiperiphery and periphery demonstrate that the underlying assumption of homogeneity of slopes is violated for this variable—the slopes for the semiperiphery and periphery differ significantly (i.e., are not parallel) from the semicore, although core and semicore slopes run parallel to one another. We remind the reader that interaction models by design tend to exhibit a high degree of multicollinearity. For example, the standardized regression coefficient for the periphery slope dummy has an absolute value of greater than unity—*prima facie* evidence of multicollinearity. So, while we have demonstrated that the slopes for the different zones are not the same through use of this technique, we cannot use it to estimate a more fully controlled and specified model. We offer instead, a more theoretically useful technique that we label a "contextual-dummy" model (reported in Table 2b), in which we report "contextual" effects for the % urban variable for all four world-system positions, while holding constant or controlling for all other variables in the model.

Turning our attention to Table 2b, we find that the coefficients for the "contextual dummy" variables indicate the zone-specific effects of % urban population are negative as we move from the semicore to the periphery. There is a significant negative effect for the periphery ($p < .05$), and semiperiphery (at the $p < .10$), similar to what was demonstrated in the interaction model shown in Table 2a. The results shown in Table 2b support the interpretation that the deleterious effects of urbanization differ across world-system positions, with negative effects occurring in the semiperiphery and periphery zones, even while controlling for all other variables in the model.

In this result, we find little evidence of a "Kuznets" effect; rather, as noted, the effects become increasingly negative moving down the hierarchy of the world-system. It bears noting that while the core and the semicore tend to be more *urbanized*, the semiperiphery and periphery tend to be more rapidly *urbanizing*. In this model, with some qualification, all other variables behave as they did in the main effects model (of Table 1). The main effect for world-system position is non-significant in Table 2b because some of its variance is captured by, or overlaps with, the "contextual dummies."

It is of note that for this model, the contextual effects for the semicore and the core are essentially the same (i.e. null). But as will be seen in subsequent runs, particularly when we test the interaction of GDP/c with world-system position, the coefficient for the semicore appears to more closely resemble that for the semiperiphery. The overall lesson here is that each of the four world-system positions appears in its own way to be uniquely related to forestation. More broadly,

Table 3 – World-System Position by Population Under Age 14 Interactions

Table 3a – Test of Different Slopes for Proportion Under Age 14 with Semi-Core the Excluded Category

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	-0.711	0.269		-2.642	0.010	
Proportion under age 14 Main Effect	-1.313	0.480	-0.538	-2.733	0.008	-0.317
Proportion under age 14 Core	0.568	0.543	0.167	1.046	0.299	-0.173
Proportion under age 14 SemiPeriphery	1.100	0.494	0.375	2.228	0.029	0.032
Proportion under age 14 Periphery	-1.584	1.897	-0.105	-0.835	0.407	-0.261
R-square = .181						

Table 3b – Contextual 4-Dummy Model for Proportion Under Age 14

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	0.068	0.904		0.075	0.940	
% Forest cover in 1990	0.003	0.007	0.047	0.467	0.642	-0.161
World-system position	-0.109	0.099	-0.215	-1.094	0.278	-0.485
Dummy (1 = less than 4% forest cover)	1.795	0.534	0.355	3.362	0.001	0.420
% Urban Population	-0.273	0.106	-0.310	-2.569	0.013	-0.458
Gross Domestic Product "PPP"	0.099	0.033	0.353	2.979	0.004	0.362
Radios per 1,000	-0.015	0.012	-0.130	-1.246	0.217	-0.387
Proportion under age 14 "Core"	0.676	0.586	0.199	1.154	0.253	-0.173
Proportion under age 14 "SemiCore"	0.088	0.548	0.022	0.160	0.873	-0.294
Proportion under age 14 "SemiPeriphery"	0.901	0.367	0.307	2.455	0.017	0.032
Proportion under age 14 "Periphery"	-1.041	1.493	-0.069	-0.698	0.488	-0.261
R-square = .553						

as one might expect for a transitional zone, the semicore appears to resemble the core in some ways, and the semiperiphery in others. It would thus be a mistake, methodologically as well as theoretically, to collapse the semicore into either of these other categories.

In the next two sets of tables (3a & b and 4a & b), we follow this methodology by disaggregating by world-system position the effects of, respectively, population under age 14, and Gross Domestic Product *per capita* (in terms of Purchasing Power Parity).

In Table 3a, we test for interaction of world-system position with changes in proportion of population under 14 with the semicore being the excluded category. Table 3a shows that the slope for the semiperiphery differs significantly from that of the semicore, the excluded category. So, as was discovered above, the assumption of homogeneity of slopes is violated.. As we move from Table 3a to Table 3b we find the same large, significant positive effect for the semiperiphery is replicated in the "contextual dummy" model.

The finding that the age cohort coefficient is significantly positive in the semiperiphery, and is negligible in the other sectors, serves as a complement to previous research (Burns et al. 1998), in which increases in *adult* population in the semiperiphery were found to be associated with deforestation. This result dovetails with earlier findings by indicating a positive effect of proportion of preadults on forest levels—but this effect only becomes apparent when controlling for the other variables, suggesting the importance of the interrelations of these social and demographic factors. It does lend qualified support to the environmental Kuznets thesis, in that the strongest effect is somewhere in the middle (in this case, in the semiperiphery), rather than at one of the ends of the world-system hierarchy.

Of course, as students of population "pyramids" (particularly as they apply in the cases of developing countries), will no doubt point out, this large younger cohort will age. As it does so, it is likely to place an increasing strain on resources. Considering this in light of previous findings that serious deforestation practices are occurring in the semiperiphery (Burns et al. 1994), there would appear to be a significant possibility of more serious environmental degradation in the near future in the semiperiphery. It also is worth considering that it is possible for a society to have already taxed the carrying capacity beyond what the overall population figures would tend to show, and even though it still will not experience the full consequences until several decades later when the next generation comes into the age of greatest resource strain. In short, it may get worse before it gets better, particularly in the semiperiphery, but perhaps in the other world-system zones as well.

Turning to our final table, we consider the interaction between world-system position and Gross Domestic Product in terms of Purchasing Power Parity (PPP). The results for the test for homogeneity of slopes are shown in Table 4a.

In Table 4a, we see that the slope for GDP/c in the periphery differs significantly form the core, semicore and semiperiphery, all of which have significantly positive coefficients. Once again the assumption of homogeneity of slopes is violated. In the fully controlled model (Table 4b), we find significant positive effects of the GDP/c variable only in the semicore and the semiperiphery; thus, it is primarily in the mid-range of the world-system that this affluence effect is most robust.

GDP/c, when interacted with zone, gives us insights into how affluence *within* a given world-system position affects forestation. This effect does indeed

Table 4 – World-System Position by Gross Domestic Product "PPP" Interactions

Table 4a – Test of Different Slopes for Gross Domestic Product "PPP" with Periphery the Excluded Category

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	–1.244	0.336		–3.704	0.000	
Gross Domestic Product Main Effect	–0.031	0.055	–0.109	–0.560	0.578	0.362
Gross Domestic Product Core	0.150	0.051	0.427	2.915	0.005	0.171
Gross Domestic Product SemiCore	0.224	0.051	0.664	4.420	0.000	0.438
Gross Domestic Product SemiPeriphery	0.097	0.045	0.455	2.158	0.034	0.067
R-square = .355						

Table 4b. – Contextual 4-Dummy Model for Gross Domestic Product "PPP"

	b	Std. Error	Beta	t	Sig.	Corr.
(Constant)	–0.593	1.218		–0.487	0.628	
% Forest cover in 1990	0.002	0.007	0.031	0.326	0.745	–0.161
World-System Position	–0.041	0.146	–0.080	–0.279	0.781	–0.485
Dummy (1 = less than 4% forest cover)	1.831	0.517	0.362	3.543	0.001	0.420
% Urban Population	–0.237	0.115	–0.269	–2.065	0.043	–0.458
Proportion under age 14	0.560	0.341	0.230	1.642	0.106	–0.317
Radios per 1,000	–0.017	0.012	–0.143	–1.430	0.158	–0.387
GDPC "PPP" "Core"	0.131	0.094	0.374	1.400	0.166	0.171
GDPC "PPP" "SemiCore"	0.196	0.067	0.582	2.915	0.005	0.438
GDPC "PPP" "SemiPeriphery"	0.084	0.032	0.392	2.597	0.012	0.067
GDPC "PPP" "Periphery"	0.075	0.070	0.170	1.069	0.289	–0.357
R-square = .576						

vary by world-system position, and it appears to have the greatest positive effects in the middle zones, with less effect for the core and the periphery. We interpret this as another of a number of manifestations of the complex nature of many of the relationships between key predictor variables and environmental outcomes.

CONCLUSIONS

Overall, our findings support our general theoretical framework, which implies that both world-system dynamics and processes identified in human

ecology are important predictors of environmental outcomes. The contextual effects demonstrated in both our interaction models and our contextual models as specified on the basis of those two sets of theories, give us a number of things to take away from this research.

As human ecology posits, population dynamics have environmental outcomes, including those related to deforestation. But as we have seen, those effects need to be qualified and contextualized, as their effects are shown to differ significantly across zones of the world system.

More generally, we might ask what the analogies of behavioral ecology for the human condition are. Certainly there are numerous lessons for humans here, particularly in terms of population dynamics. Yet one of the worst mistakes we could make would be to apply *any* finding from behavioral ecology without some thought about what is analogous and when. We have seen an example of the cohort effect to which all species are subject; but we also saw how that effect is tempered by world-system position.

The ability to overshoot the earth's carrying capacity needs to be seriously considered. Overshoot can take place in terms of population, affluence or technology, or some combination thereof, yet overshoot in each area is somewhat idiosyncratic. Overshoot in population terms is seen in the relative life chances of generations (e.g. Easterlin 1980). Here, it is possible to overshoot and not see the effects until literally a generation or so later. Some insight into the problem, however, comes from looking closely at cohort effects based on behavioral ecology theory.

As has been noted in a number of studies (e.g. Bergesen 2001; Bergesen and Bartley 2000; Bergesen and Parisi 1997; Burns et al. 1994, 1997, 1998; Ehrhardt-Martinez et al. 2002; Roberts and Grimes 1997, 1999, 2002), the greatest strain on the environment, at least until recently, has been seen in rapidly *developing* countries of the world. While these clearly involve the semicore and semiperiphery, for reasons detailed above, the periphery increasingly is drawn into the (bottom of) the world-system and, in some ways faces some of the same situations as the semiperiphery—except with disadvantages not only relative to the core, but to virtually the rest of the world, including the semiperiphery.

A fruitful strategy for future researchers, along with identifying social processes that lead to environmental impact, is to try to isolate *where* and *when* those processes either are or are not operational, and what the *conditions* are that make them so. A unifying theory may emerge in the future, but before such a theory can meaningfully simplify the field, we need to embrace more complexity in our theorization.

In this paper, we have focused primarily on world-system processes, not only alone but when controlling for, and in some cases interacting with, population variables and a measure of national affluence. Research could just as easily be focused around some other aspect of the overall model. We suggest that, rather than testing one small aspect of a given theory against some aspect of another, and then concluding, based on that particular test, that one theory is supported and the other refuted, we must take seriously the question of theoretical scope conditions. At least for the time being, to be effective, any policy interventions must take scope into account. As a case in point, consider the well-meaning but largely misguided "Green Revolution," which assumed the farming principles developed in temperate regions were universal, and therefore could be applied in a largely unmodified fashion to the Third World, without properly accounting for context. In addition to the obvious differences in social organization, the soils in the largely tropical Third World are quite different from those in the largely temperate developed world. Thus, to embrace the universal principal of being "ecologically sound" in both places, would lead to very different practices in those places, because the same practices would have different outcomes, depending upon where they were implemented (c.f. Colinvaux 1980).

Likewise, in attempting to understand macro-level causes of deforestation, the view that "one model fits all" is inadequate. Rather, as our work demonstrates, it is important to consider contextual effects, particularly in terms of world-system dynamics. Such considerations might include adopting methodological procedures similar to those here, where the homogeneity of world-system slope dummies is empirically ascertained and, as appropriate, models are subsequently estimated based on slope-dummies and other pertinent regressors. If the field is to progress, it is crucial for us to embrace some of these complexities in our theorization and empirical work, including the modeling of non-linearities and interactions of the sort we have examined here.

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Appendix A. Countries in Analyses (N=73)

Core	FRSTP900	FRST_90
United Kingdom	0.76	9.87
Spain	0.58	27.05
Switzerland	0.34	29.23
Italy	0.28	33.01
Netherlands	0.25	10.77
Denmark	0.20	10.49
United States	0.16	24.25
Japan	0.01	65.97
Sweden	0.00	65.91
Belgium	-0.16	22.58
N of cases 10		

Semi-Core	FRSTP900	FRST_90
Israel	5.54	3.98
Ireland	3.16	7.10
Portugal	1.67	33.84
Greece	0.83	25.59
New Zealand	0.47	28.20
Hungary	0.37	19.15
Norway	0.33	27.89
Austria	0.18	46.04
Finland	0.03	71.75
Australia	0.00	20.58
Brazil	-0.36	65.60
N of cases 11		

Periphery	FRSTP900	FRST_90
Bangladesh	1.28	8.98
Congo, Rep.	-0.07	65.11
Central African Republic	-0.12	37.25
Senegal	-0.61	34.57
Mali	-0.64	11.62
Cameroon	-0.77	56.03
Madagascar	-0.83	22.18
Sudan	-1.22	29.97
Benin	-1.90	30.27
Malawi	-1.94	35.16
Zambia	-1.95	53.48
Sierra Leone	-2.32	19.77
Cote d'Ivoire	-2.47	30.71
Togo	-2.64	13.22
Rwanda	-2.98	18.52
Burundi	-5.55	9.38
N of cases 16		

Semi-Periphery	FRSTP900	FRST_90
Egypt, Arab Rep.	3.57	0.05
Algeria	1.29	0.79
Tunisia	0.20	3.21
Turkey	0.20	13.00
India	0.05	21.44
Dominican Republic	0.00	28.44
Saudi Arabia	0.00	0.70
Singapore	0.00	3.28
Syrian Arab Republic	0.00	2.55
Morocco	-0.04	6.80
Korea, Rep.	-0.07	63.84
South Africa	-0.08	7.37
Chile	-0.12	21.02
Guyana	-0.25	88.21
Colombia	-0.34	49.59
Congo, Dem. Rep.	-0.34	61.99
Peru	-0.36	53.05
Venezuela	-0.38	58.59
Paraguay	-0.45	61.92
Kenya	-0.47	31.67
Thailand	-0.64	31.09
Costa Rica	-0.68	41.64
Trinidad and Tobago	-0.71	54.78
Honduras	-0.90	53.37
Mexico	-0.93	32.23
Indonesia	-1.01	65.20
Ecuador	-1.05	43.09
Philippines	-1.21	22.39
Jamaica	-1.30	35.00
Sri Lanka	-1.38	35.39
Panama	-1.39	45.61
Guatemala	-1.44	31.24
Ghana	-1.45	33.12
Nigeria	-2.07	19.22
Nicaragua	-2.39	36.66
El Salvador	-3.39	9.31
N of cases 36		

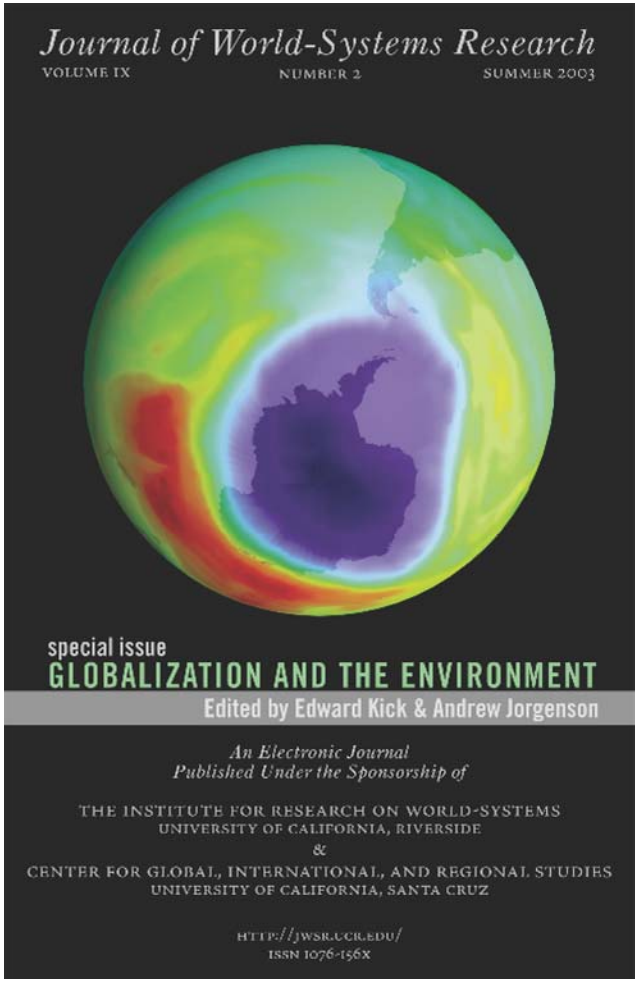
Appendix B – Descriptive Statistics and Correlations (N=73)

Means and Standard Deviations

	Mean	*Std. Deviation*
Ave. Annual Change in % Forest Cover 1990–2000	–0.41	1.50
% Forest Cover in 1990	31.40	20.76
World-System Position	6.25	2.96
Dummy (1 = less than 4% forest cover)	0.10	0.30
% Urban Population	1.65	1.70
Proportion under age 14	–0.62	0.61
Gross Domestic Product "PPP"	10.17	5.34
Radios per 1,000	11.33	12.90

Correlations

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Change in % Forest Cover 1990–2000	1.000	–.161	–.485	.420	–.458	–.317	.362	–.387
2. % Forest Cover in 1990	–.161	1.000	.047	–.463	–.054	–.072	–.038	.050
3. World-System Position	–.485	.047	1.000	.004	.517	.631	–.382	.374
4. Dummy (1 = less than 4% forest cover)	.420	–.463	.004	1.000	–.123	–.010	.140	–.144
5. % Urban Population	–.458	–.054	.517	–.123	1.000	.505	–.032	.503
6. Proportion under age 14	–.317	–.072	.631	–.010	.505	1.000	–.531	.409
7. Gross Domestic Product "PPP"	.362	–.038	–.382	.140	–.032	–.531	1.000	–.070
8. Radios per 1,000	–.387	.050	.374	–.144	.503	.409	–.070	1.000

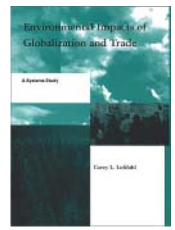


Lateral Pressure and Deforestation

Andrew K. Jorgenson

Lofdahl, Corey L. 2002. ***Environmental Impacts of Globalization and Trade: A Systems Study.*** Cambridge, MA: The MIT Press. 253 Pages, ISBN 0-262-12245-6 (Cloth). http://mitpress.mit.edu

What are the effects of increased structural integration of international trade on the environment of relatively poorer countries, particularly in the southern hemisphere? This is the key question addressed by Corey Lofdahl in his book *Environmental Impacts of Globalization and Trade: A Systems Study*. Given the theme for this special issue of the *Journal of World-Systems Research*, a discussion and evaluation of this book seems rather timely and relevant. An immediate fact of interest is that Lofdahl is not an environmental sociologist, let alone acquainted with relevant empirical works grounded in a world-systems perspective. Rather, he is trained as a political scientist, and works in the simulation and information technology sector.



This book uses lateral pressure theory analytically and a variety of methodological steps (GIS, time-series, multivariate analysis, simulation modeling) to test how and to what extent the aforementioned theory in an expanded form explains the effects of international trade on environmental outcomes, more specifically deforestation in relatively poorer countries. The text consists of six chapters and a series of appendices that contain more in-depth discussions of the methods and data included in the analyses. Below I offer critical summaries of each chapter in succession, followed by a brief evaluation of the text.

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Chapter one begins with a discussion of the recent protest events in Seattle during the WTO meetings, currently a relatively common topic among social scientists. Lofdahl, like many others, explains that the protesters in Seattle were not against globalization, but rather protesting the harmful effects inflicted by it on the global environment and poorer disadvantaged populations around the world. Economists argue that free trade helps "developed" and "less-developed" nations grow economically while environmental and social justice groups maintain that increased unregulated trade caused by globalization decreases regional labor standards and environmental conditions in "less-developed" countries at the expense of the more "developed" countries' interests. Simply, protestors maintain that trade and globalization hurts human well-being and the environment, a direct contradiction to economists, which generally believe that trade helps communities develop and the environmental outcomes are justified. This debate is nothing new to the social sciences, especially macrosociologists.

Another common topic in related areas of literature is definitional discussions regarding what we really mean by the term globalization. Lofdahl immediately takes part in this dialogue by offering a definition, which he operationalizes in this study. His definition is of the structural integration sort, rather similar to that offered by Chase-Dunn et al. (2000, 2002), with a focus on trade while clarifying that it also refers to other variations of international interaction. Following this definitional clarification, two additional areas of literature are reviewed from a political science perspective: (1) politics and markets, and (2) geopolitics and power. During the latter, Lofdahl briefly mentions Wallerstein's early (1979) notions of the core and periphery, but misinterprets their hierarchical and relational characteristics by equating them to horizontal concepts that connote spatial differentiation among geographic units of similar scale (pg 21). This leads to the greatest weakness of the book, whether intentional or unintentional: an almost total neglect—with the exception of this misinterpretation—of references and connections to areas of relevant political-economic, political-ecological, and environmental sociological literatures. However, this shouldn't entirely discount its methodological contributions as discussed below, but it does cloud them up a bit.

Chapter two provides a description of lateral pressure theory (LPT), the theoretical framework applied to a series of analyses in later chapters. This framework argues that as states develop economically and their populations increase, they make demands on international resources, called lateral pressure, and these demands lead to an increase of military force and the likelihood of warlike conflict. Lofdahl attempts to extend LPT with the intention of capturing the international-level, systemic interconnections that contribute to global environmental degradation (pg 45). More specifically, in this text LPT is used

to account for the expansive behavior of multinational corporations acquiring worldwide market share after World War II, which leads to the focus on international trade, and moving away from state centric analyses (pg 49). In doing so, Lofdahl distinguishes between four interconnected levels of analysis: the individual, the state, the international system, and the global system. Going from top to bottom, global processes effect the international system, which in turn effects the state, and so on. And, going from bottom to the top, the same logic applies.

A primary goal of this study is to explicitly identify a geographical component nested within LPT. The selection of forest change as a dependent variable overlaps considerably with this goal. Forest change, or deforestation, implies a spatially observable and measurable outcome grounded in actual locations, and Lofdahl's proposition states that the "expansion of the social environment through globalization and trade impacts the natural environment as measured by forest change" (pg 53). In the following three chapters, findings from a series of analyses attempting to test this proposition are reported. Building on one another, they involve different yet complimentary methods.

Chapter three consists of series of geographical and time-series analyses. The geoanalyses, offered in map form, are presented to introduce the primary dependent variable addressed in this text—forest change (i.e. deforestation), and a few related variables of interest, which offer visual descriptions of their spatial distribution. The time-series analyses address how deforestation, GNP, CO_2 emissions, imports, exports, population, and forest change have varied over time.

The geographical analyses illustrate that countries with relatively larger shares of global GNP than population are generally clustered in northern (core) regions while those with more population than GNP tend to be in southern (peripheral) regions. Moreover, most CO_2 emissions are generated in the north, while relatively higher levels of deforestation occur in the south. As accurately stated, we see that global-scale data can be displayed in geographical units other than states (pg 77), particularly of relevance for natural endowments, which do not correspond with geopolitical borders. These visual descriptions are rather effective, especially for world-systems oriented scholars generally bound to cross-national data. With this mapping approach, one can create visual images that identify the world-systemic—as well as international—contours of certain kinds of conditions, especially environmental and ecological. Lofdal undoubtedly illustrates how this methodology improves the descriptive power (at least) of these kinds of empirical studies. Other recent cross-national analyses of deforestation (studies that Lofdahl does not address) would greatly benefit from the incorporation of this methodology (e.g. Burns, Kick, Murray and Murray 1994; Kick, Burns, Davis, Murray and Murray 1996; Ehrhardt-Martinez 1998; Jorgenson 2002).

Time-series analyses are performed to establish initial connections and correlations among the set of variables listed above over a period of time. Results are what one familiar with relevant studies would expect, and offer additional support for the geographical analyses. Lofdahl identifies GNP as a proxy indicator for technology, stating that "technology here represents the sum of applied knowledge and skills, both mechanical and organizational… in other words, technology consists of the means whereby humans transform and use nature for their own benefit, a process that includes but is not limited to nature, people, competition, and economics" (pages 79–80). I consider this application somewhat problematic for the following reasons. First, and most importantly, GNP per capita is a more accurate indicator of affluence (Dietz and Rosa 1994), development (e.g. Burns, Kentor, and Jorgenson 2003; Jorgenson and Burns 2003), a proxy for consumption (Wackernagel et al. 2000; York, Dietz, and Rosa 2003; Jorgenson 2003), but not technology. More appropriate indicators of technology include GNP per worker, or proportion of total GNP in service (Dietz and Rosa 1994: York et al. 2003). Granted, all three are relatively highly correlated, but not identical. Second, Lofdahl fails to discuss how GNP partly measures relative power between countries in the world-economy (Chase-Dunn 1998; Kentor 2000). Moreover, he lumps all countries into two categories, "developed" and "less developed," which hides the heterogeneity in the non-core between more peripheral and semiperipheral countries, and within the semiperiphery itself (Chase-Dunn and Hall 1997; Chase-Dunn 1998).

Chapter four contains a series of bivariate and multivariate statistical analyses that address causal relationships between variables explored in the previous chapter. Rather than performing and reporting a simple test of correlations, Lofdahl provides results of bivariate regression analyses which test the effects of (1) GNP per capita on CO_2 per capita, (2) population growth on CO_2 per capita, (3) population growth on forest change, and (4) GNP per capita on forest change. Findings indicate that all regression coefficients are statistically significant, but coefficients of determination (R^2) are not reported in the body of the chapter. A simple analysis of correlations between these variables would be just as effective and easier to follow.

In the second part of chapter four, Lofdahl develops an indicator similar to import or export partner concentration,[1] but takes it a step further. The new indicator, "trade connected times GNP" (TC x GNP), generates a value that

[1] Partner concentration refers to the percent or proportion of total exports or imports to a country's largest trading partner (Kentor 2000).

depends both on the amount a country trades with its partner and the size of that partner's GNP (pg 119). Mathematically, it is calculated by cross-multiplying trade connections (proportion of a country's total imports or exports) with the GNP of each associated trading partner, and then summing these values. Lofdahl constructs this index for both imports and exports, but focuses on imports in the reported multivariate analysis.[2] He considers this index to be an international variable whereas variables such as GNP per capita and population growth are domestic indicators.

While I consider this new indicator to be a **critical** empirical and methodological development for the social sciences, the use of total GNP instead of or in addition to GNP per capita is problematic. Lofdahl sates that GNP per capita is not included because "it matters little whether a trading partner's large GNP is due to high technology and low population or low technology and high population" (pg 119). This justification, coupled with his justification for treating per capita GNP solely as an indicator of technology illustrates a limitation of this study. Many of the relatively poorest (per capita wealth) countries in the world contain higher total GNPs than some of the relatively wealthiest countries (per capita wealth). Per capita wealth (GNP or GDP), which is highly correlated with a country's relative position in the core-periphery hierarchy, is also very highly positively correlated with per capita consumption, and negatively correlated with deforestation (Wackernagel et al. 2000; York et al. 2003; Jorgenson 2002, 2003; Broswimmer 2002). At minimum, both total and per capita GNP should be included, meaning the construction and analysis of two trade-connected indicators.

This leads to a multivariate analysis in which forest change is regressed on (1) TC x GNP, (2) GNP per capita, and (3) population growth. All three regression coefficients are statistically significant, with TC x GNP's effect on forest change the strongest (negative), followed by population growth (negative) and GNP per capita (positive). In sum, while increased GNP per capita leads to forestation, higher trade connectedness with partners with higher GNPs, and relatively higher levels of domestic population growth lead to relatively higher levels of deforestation. Thus, deforestation is a function of both domestic (GNP and population) and international (TC x GNP) factors. Although the development and incorporation of this new indicator is an advance for empirical work concerning environmental outcomes, Lofdahl's multivariate analysis particularly

[2] Lofdal explains in an endnote (43) that the results for imports and exports are almost identical due to the high correlation between the two.

illustrates the key limitation of this book, resulting from the neglect of other relevant studies of deforestation (e.g. Burns et al. 1994; Kick et al. 1996; Ehrhardt-Martinez 1998; Jorgenson 2002). These other analyses illustrate that the current model, which specifies three independent variables, is too parsimonious. For example, deforestation may result from three types of dependency: export/trade dependency, debt dependency, and foreign capital penetration (Ehrhardt-Martinez 1998). Hence, the greater the rate of dependency on core countries, the greater the rate of deforestation. Dependency indicates that high levels of domestic inequality will result in increased levels of deforestation as the rural poor become increasingly impoverished, rely more heavily on forest resources, and search for nonagricultural activities to supplement or replace their agricultural income (Ehardt-Martinez 1998; Jorgenson 2002).

Empirical findings also suggest that deforestation is most severe in semiperipheral regions (Burns et al 1994; Kick et al 1996; Jorgenson 2002).[3] Population growth has a positive effect on deforestation in all regions of the world-economy, but its effects are intensified in the semiperiphery (Kick et al. 1996). However, rural population growth is a better predictor than total population growth. Increased urbanization in semiperipheral regions causes landless workers to migrate out of urban areas into forested regions, a process labeled rural encroachment (Burns et al. 1994). Moreover, landless workers contribute to deforestation through their limited knowledge of agricultural practices (Burns et al. 1994). Semiperipheral countries tend to have lax environmental policies and because of the potential for economic development are more eager to reap the perceived economic benefits of deforestation than core countries (Smith 1994; Bergesen and Bartley 2000). On average, these countries possess greater technological capacities to deforest than peripheral regions do (Kick et al. 1996).

International trade in forest products is another factor effecting deforestation. Core countries are able to export forest products without high levels of deforestation because they often possess the means and technology necessary for reforestation practices (Kick et al. 1996). In semiperipheral countries, both the import and export of forest products impacts deforestation (Kick et al. 1996). Exportation of forested products increases deforestation due to the lack of reforestation practices. Importation of forest products is an indicator of infrastructure building and development, which increases deforestation directly through land acquisition and development (Kick et al 1996).

[3] However, Tom Burns, Edward Kick, and Byron Davis have found that levels of deforetstation are increasing in the periphery relative to the semiperiphery—at least in the last decade (see their article in this special issue).

Like Lofdahl, these other empirical studies include GNP per capita and population as independent variables. However, by themselves they potentially elevate the effect of the newly constructed indicator of trade connectedness. To adequately test this indicator's effect on deforestation, an analysis should control for the additional factors discussed above. Furthermore, population needs to be specified in both urban and rural, and considering the robust evidence concerning higher levels of deforestation in the semiperiphery, Lofdahl's "less developed" category needs restructuring. Since his analyses are not grounded in a world-systems perspective, a simple solution might include the incorporation of a "middle income" (GNP per capita) dummy variable.

In chapter five a series of simulation models are presented that "provide a link between the systemic assumptions and dynamic responses necessary to explain the preceding time-series and statistical analyses" (pg 136). The final model, labeled the environmental lateral pressure model (ELP), incorporates the three key factors of interest throughout the book: population, technology (measured as GNP per capita), and resources (measured as forest change). Moreover, model feedback loops are applied to help make sense of the "transition from a system's microfeatures to its macrobehavior" (pg 141).

This study argues that trade provides a mechanism by which the costs of industrialization are pushed off by rich countries onto poor ones (pg 157). The ELP model in its presented form supports this argument. It depicts the developed northern countries exporting technology and high value goods to southern relatively poorer countries, while the latter export natural resources to the former. These relational characteristics create asymmetric outcomes: relatively higher economic development and a healthier environment for northern countries, and economic underdevelopment and increased environmental degradation for southern countries. Overall, findings are supported by the literature reviewed in earlier chapters, not to mention the neglected sociological areas of literature concerned with the "global treadmill of production" (e.g. Schnaiberg 1980; Schnaiberg and Gould 1994) and the "Netherlands fallacy" (e.g. Ehrlich and Holdren 1971; York et al. 2003; Rosa and York 2002; Jorgenson 2002, 2003). The level of sophistication involved is quite impressive and the analyses illustrate the utility of simulation modeling for studying global-level phenomena while paying attention to different levels of analysis. However, the underspecification of the multivariate analyses in chapter four also seriously impacts the simulation models developed here. Like chapter four, one must applaud Lofdal's methodological efforts and advances but be wary of his empirical findings.

The final chapter provides a brief conclusion of the book's findings, theoretical and methodological contributions, policy implications, and future steps for this research agenda. Each of these sections is well written, offering clear and concise narratives of the steps taken in the preceding five chapters. Policy implications discussed are rather reminiscent of recent empirical works that challenge the environmental Kuznet's curve (Grimes and Roberts 1995; Roberts and Grimes 1997) and dependency and world-systems perspectives that challenge modernization theory's approach to domestic development.

In summary, Lofdahl attempts to expand and operationalize lateral pressure theory to better explain if and how international trade impacts the environment. Using a series of complementary geo and statistical methods, empirical findings suggest that trade does impact the environment—in this case forested areas, particularly for southern countries with relatively lower levels of per capita GNP, relatively higher levels of population growth, and relatively higher levels of trade connectedness with partners (other countries) that possess relatively higher total GNPs. This book warrants notice due to its application of sophisticated statistical methods and especially the development of a trade connectedness indicator that expands and greatly improves upon trade partner concentration as a predictor of various environmental and well being outcomes, in this case deforestation. With these strengths and contributions comes a general noticeable weakness: the neglect and/or misinterpretation of relevant theoretical perspectives and empirical studies. This is particularly evident in the literature review provided in the first two chapters, and especially the underspecification of the multivariate analysis in chapter four and the simulation models in chapter five. This underspecification potentially biases the reported empirical findings. However, the indicator developed by Lofdahl is a noteworthy advance for studies of various international and world-systemic processes and with slight changes should definitely be incorporated into future relevant analyses. Furthermore, his application of simulation modeling and especially geoanalysis illustrate the utility of these methodologies for all social scientists, and like the new trade connected indicator, their addition to future analyses would be greatly effective.

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Book Reviews

Franz J. Broswimmer
Ecocide: A Short History of Mass Extinction of Species
Reviewed by Florencio R. Riguera

Arthur Mol and Frederick Buttel (eds)
The Environmental State Under Pressure
Reviewed by Bruce Podobnik

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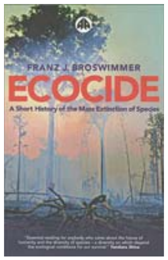
Broswimmer, Franz J. 2001. ***Ecocide: A Short History of Mass Extinction of Species.*** London: Pluto Press. 204 pages, ISBN 0-7453-1935-1 (cloth), ISBN 0-7453-1934-3 (paper). http://www.plutobooks.com/

Ecocide calls attention to the threat of unsustainable relationships between humans and the environment, and argues for the need to respect the limits the carrying capacity of the latter imposes. Humans depend on the environment; and degrading it is ultimately harmful to them. The book employs an interdisciplinary approach—utilizing materials from both the natural and the social sciences. It thus covers a broad range of mechanisms that have environmental degradation among their consequences. This brief story of mass extinction of species comes through with illustrative cases of societies in antiquity that ended up overshooting the carrying capacity of their environment.



However, Broswimmer correctly focuses on the fact that environmental conditions result from the actions of human populations in different areas of the globe in different periods. He shows that the current trend of accelerated mass extinction and loss of biodiversity is traceable to the capacity of humans for culture (that is, intelligence and language) along with the emergence of the system of capitalism. Intelligence and communication made learning feasible and enabled societies to solve their problems. But the experience also led to an attitude that held the environment as an unlimited resource. Under capitalism, resources would be utilized to realize profit, and the tendency was to externalize costs.

This drives the point that actions of human populations are socially organized. To understand the link between said actions and environmental degradation, one needs to look into the goals earlier societies pursued; the implements or technologies they employed; or the division of labor they followed. These can serve as the backdrop against which one may appraise the current environmental situation. The consequences of human actions in terms of environmental degradation may not be disregarded.

These actions need not directly intend to destroy a human ecosystem—Broswimmer extends the understanding of "ecocide" so that it includes actions or arrangements that as much as allow or just facilitate environmental degradation. This broadened understanding is useful for identifying decision points as well as for constructing a discourse in dealing with the human-environment relationship. The task is to ensure a balance between resource utilization and sustainability. There is a trend of accelerated mass extinction of species and loss of biodiversity—*Ecocide* provides tables of data that illustrate likely trajectories

toward environmental degradation. Nevertheless, there is hope. The impending catastrophe can be averted if societies devise and implement measures that respect the environment. And these measures are very likely to impact current patterns of production and consumption. More importantly, the measures would also entail a revised understanding of interest between societies on the globe.

In the present global context, it is necessary to take into account the operations of large transnational corporations, which have the ability to influence policies or arrangements between nation-states. These have an effect on the trading of new products to other populations, or, on the dumping of toxic waste somewhere in the environment. Through policies traceable to nation-states, poorer nations can be pushed to exploit their resources—with costs to the environment—say, in efforts to repay their debt. Mechanized warfare is another factor that deserves attention. The use of toxic materials to pursue military objectives can jeopardize non-combatant populations in the long run. Of course, destruction of the environment on which the opposing side depends for its resources can be directly intended in warfare. In addition, because of the inherent competition between nation-states for dominance in the global arena, *Ecocide* contends that the system of nation-states ultimately have harmful effects on the environment.

However, when *Ecocide* offers the alternative of ecological democracy and visualizes an equitable global commons to avert human-induced ecocide one can raise questions on the feasibility of implementing the proposed vision. Under ecological democracy, individuals and communities must participate in the formulation of measures/policies that affect their lives, and their participatory rights must be safeguarded. Humans must also take into account the interest of other creatures—a view that opposes treating the environment simply as a resource. The book rightly recognizes the role of social movements in exposing otherwise invisible mechanisms that lead to environmental degradation. But social movements usually articulate their claims ultimately to nation-states. And when they succeed in persuading communities or publics, the latter are expected to influence the policies managed by nation-states. Hence, the system of nation-states is not willy-nilly harmful to the environment—it is a matter of crafting and implementing appropriate policies.

The project of an equitable global commons also needs the participation of nation-states—at least, in the interim. The current debate on the patenting of indigenous knowledge calls attention to differences in power between nation states. When an alternative system of governance is in place, there will still be the issue of whether or not developing nations must follow the path taken by the developed nations. Broswimmer sees some solution in less-damaging technologies going from the developed nations to developing nations. This apparently does not question the benefits of technological development. Nevertheless, one can ask—what of ideas going the other direction? When the developing nations participate in ecological democratic processes, is there no possibility that views and values from the periphery could offer a critique of some of those in the core? Questions like these can put the ratchet-effect in relation to what levels of efficiency or comfort populations in the developed countries might not be willing to part with.

If a sustainable environment should have a role in the devising of ways to guide human populations in dealing with their immediate environment it is inevitable to have an understanding of how other populations would like to deal with their own immediate environment. The developed nations wield considerable power in the design of global arrangements. But it is important to ensure that the substance of these arrangements promote goals that take environmental linkages into account. The project is one of choosing what goals to pursue in a global context—and how to define these goals in a shared environment.

Ecocide organizes a huge body of current information and perspectives on the environment. It links various discourses to the problem of an impending ecocide—broadly understood. And it candidly drives home the point of a long-term perspective is imperative to arrest the trend toward ecocide. It brings to the foreground the underlying complex links through which societies end up degrading the environment. Its theme and its message are persuasive and easy to grasp. Broswimmer thus provides a useful educational tool in *Ecocide*.

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Arthur Mol and Frederick Buttel (eds). ***The Environmental State Under Pressure.*** Amsterdam and Boston: JAI, 2002, viii + 267 pages, ISBN 0-7623-0854-0 (cloth). http://www.elsevier.com

The last thirty years have witnessed the rise and partial demise of state-based efforts to protect the environment at local, national, and international levels. As described in the useful collection of articles published in this volume, the 1960s witnessed the emergence of agencies within core nations as well as within some nations in non-core regions that were endowed with broad legal and regulatory authority to protect specific ecosystems from irreparable degradation. Since the 1980s, however, these 'environmental states' have come under sustained attack, first by individual governments that pushed deregulation and market-based

regulatory approaches, and then by pressures exerted by corporate forms of globalization. As demonstrated in *The Environmental State*, the result has been a general weakening of state-based efforts to protect ecosystems.

The volume examines the new challenges facing the environmental state by gathering together a diverse set of theoretically-driven or case-study analyses. In many respects, the strength of the volume lies in its theoretical and geographic heterogeneity. The volume begins with chapters that sketch out two different theoretical interpretations of the shifting fortunes of the environmental state: the treadmill of production approach (summarized in the book by Schnaiberg, Pellow, and Weinberg), and the ecological modernization perspective (sumarized by Mol and Spaargaren). These chapters highlight the divergent lessons that can be drawn from recent changes in the efficacy of state-based approaches to environmental reform. Whereas the treadmill of production perspective argues that capitalist states have never sufficiently prioritized ecological sustainability, the ecological modernization maintains that possibilities exist to construct states that are supportive of both market accumulation and ecological protection. A number of the analyses that follow these opening essays touch, explicitly or implicitly, on this debate between more and less dire interpretations of the relationship between markets and ecological degradation. The subsequent chapters also find authors drawing on theoretical lessons from Habermas, Giddens, and Foucault to interpret the changing nature of the environmental state.

In addition to its theoretical diversity, the volume does an impressive job of presenting analyses from across the world. Chapters address the evolution of state-based environmental policies in the United States, Finland, Portugal, the Netherlands, Cameroon, Tanzania, China, Thailand, Vietnam, and Russia. Of particular interest is the chapter by Jokinen, which explores the emergence of the 'suprastate' of the European Union and its impact on environmental policy making in Finland. Here we have an opportunity to see how the consolidation of a regional political authority is influencing policies carried out within a specific nation. All of the case-studies are richly detailed, and raise intriguing questions about the viability of state-based environmental regulation in this era of advancing markets and corporate-driven forms of globalization. World-systems scholars will particularly appreciate this volume for its extensive treatment of events in the non-core world.

While The Environmental State provides an impressively diverse set of chapters, the editors make little attempt to draw general lessons from their broad collection of studies. The introductory chapter by Mol and Buttel highlights key dilemmas facing state-based approaches to environmental regulation, and briefly reviews the articles in the volume. The editors point out that the case studies do not try to verify or falsify the treadmill of production or ecological modernization perspectives; instead, the authors in the volume show the partial relevance of each approach. There is no concluding essay either, which would certainly have been useful in placing the various cases into a broader perspective. The message that emerges from the volume by default is that complex dynamics are taking place in locales across the world, and that the environmental state is being undermined by a variety of different factors. Specific market dynamics are shown to have been partially reformed in certain areas, but market dynamics are also shown to be encouraging ecological degradation in other regions. A stronger concluding position should have been taken by the editors on the extent to which markets can be reformed, through state intervention, on local, regional, and global levels.

Readers schooled in the world-systems perspective are likely to be left with many unanswered questions after having read this collection of studies. Given that virtually every case study demonstrates the declining efficacy of national-level, state-based environmental regulation, what might be a potential alternative? Do the studies as a whole suggest we place our hope in something like a global environmental state that might implement more effective environmental regulation? Or do the studies suggest instead that the national environmental state will continue to wither, and capitalist dynamics will gain further freedom to disrupt ecosystems? Discussion of these large issues would have strengthened what is a still useful and diverse compendium of studies.

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