# FOOTPRINTS ON THE EARTH: THE ENVIRONMENTAL CONSEQUENCES OF MODERNITY

**RICHARD YORK**
*University of Oregon*

**EUGENE A. ROSA**
*Washington State University*

**THOMAS DIETZ**
*Michigan State University*

*Growing evidence demonstrating clear threats to the sustainability of the ecosystems supporting human societies has given rise to a variety of sociological theories of human-environment interactions. These environmental impact theories fall into three general perspectives: human ecology, modernization, and political economy. These theories, however, have not been empirically tested in a common analytic framework. Here, a framework that relies on ecological principles is adopted and modified. Using a revised stochastic formulation of that framework and the most comprehensive measure of environmental impact to date—the ecological footprint—the factors driving the environmental impacts of societies are assessed. The overall findings support the claims of human ecologists, partially support the claims of political economists, and contradict the claims of modernization theorists. Basic material conditions, such as population, economic production, urbanization, and geographical factors all affect the environment and explain the vast majority of cross-national variation in environmental impact. Factors derived from neo-liberal modernization theory, such as political freedom, civil liberties, and state environmentalism have no effect on impacts. Taken together, these findings suggest societies cannot be sanguine about achieving sustainability via a continuation of current trends in economic growth and institutional change.*

**THE HISTORY** of sociology is punctuated with the presupposition that the environmental sustainability of societies is unproblematic (Buttel 1987; Dunlap 1997; Goldman and Schurman 2000). Ecological limits and threats to sustainability, principal lessons of the twentieth century, have seriously challenged that presupposition.[1] Substantial human impacts to ecosystems predate the modern era by thousands of years (Turner et al. 1991). However, the scale of those impacts has increased extraordinarily in the modern era, dramatically altering the global environment, including the land cover over vast areas of the earth (e.g., desertification and deforestation), the number and distribution of species (e.g., extinction of flora and fauna), the chemical composition of the atmosphere (e.g., ozone depletion and accumulation of greenhouse gases), and the availability of resources (Harrison and Pearce 2000; Turner et al. 1991; Vitousek et al. 1997).

The recognition that the ecological sustainability of human societies is now in serious question has given rise to sociological theo-

Direct all correspondence to Richard York, Department of Sociology, University of Oregon, Eugene, OR 97403-1291 (rfyork@darkwing.uoregon.edu). We thank Kenneth Bollen, Brett Clark, Michael Dreiling, Riley Dunlap, John Bellamy Foster, David John Frank, Theresa Koford, Timmons Roberts, Thomas Rotolo, Alexis Vásquez, and the *ASR* Editors, a deputy editor, and the anonymous reviewers for their important contributions.

[1] Nisbet (1982), reflecting on the rise of the twentieth century's awareness of environmental limits and anticipating the judgments of future historians, wrote: "When the history of the twentieth century is finally written, the single most important social movement of the period will be judged to be environmentalism" (p. 101).

rizing addressing the role of the environment in societies (Dunlap et al. 2002). One version of this theorizing is the "greening" of classical theory, a revisit to the mine of classic thought to excavate its previously overlooked environmental insights (e.g., see Dickens 1992; Foster 1999). Another version—from the perspectives of human ecology, modernization, and political economy, which is our focus here—is devoted to understanding how human societies impact the physical environment. Taken together, we refer to these as environmental impact theories.

These environmental impact theories, however, have not yet been empirically tested in a common framework. Although these theories share important common ground, on several key points they make strikingly different predictions of how humans affect the environment. Adopting a framework from ecological science that relies upon ecological principles, the IPAT model—a well-known model in the natural sciences and in the emerging field of industrial ecology (Graedel and Allenby 1995)—we assess the predictive capability of the environmental impact theories. We use as our indicator of environmental impact the "ecological footprint," the most comprehensive measure of environmental impacts available. This measure allows comparison across types of impacts by estimating the quantity of land that would be required to support the material consumption of a nation.

We assess the relative explanatory power of the leading environmental impact theories in five steps. First, we outline the IPAT framework, demonstrate its amenability to sociological analyses, and develop a model appropriate for empirical testing. Second, we describe our measure of environmental impact, the ecological footprint. Third, we provide a synopsis of each impact theory to be tested. Fourth, we enter the key theoretical variables into our analytic framework. Fifth, we use the analytic framework to assess each of the theory's predictions.

## THE ECOLOGICAL ANALYTIC FRAMEWORK

What are the driving forces that produce the environmental impacts threatening sustainability? Decades of debate over this question have taken place in ecological science within the framework of the IPAT formulation (Harrison and Pearce 2000; Stern, Young, and Druckman 1992).[2] IPAT specifies that environmental *I*mpacts are the multiplicative product of *P*opulation, *A*ffluence (per capita consumption or production), and *T*echnology (impact per unit of consumption or production), hence:

$$I = PAT. \tag{1}$$

IPAT analyses typically take the following form (using carbon dioxide emissions as an example):

$$CO_2\ emissions = (Population) \times (GDP\ per\ capita) \times (CO_2\ emissions\ per\ unit\ of\ GDP).$$

This type of specification allows for assessing the potential effect on an impact of changes in any of the independent variables. However, the validity of the specification is assumed a priori.

Owing to its accounting formulation and to its simple conceptualization (e.g., it omits many factors of interest to social scientists or subsumes them in the *T* term), IPAT has not received widespread attention in sociology. But, because the IPAT framework captures fundamental features of ecological principles, our approach is to reformulate IPAT in stochastic form and to refine it so that it is amenable to the testing of sociological theory. The modified IPAT—called STIRPAT—can serve as a common analytic framework for assessing the empirical expectations of a variety of sociological theories.

### THE REFORMULATION OF IPAT

In its original form IPAT is inappropriate for hypothesis testing because it is an accounting equation or identity (i.e., it specifies the relationship between *I* and *P*, *A*, and *T* as proportional a priori and assumes no error term). To overcome the limitations of the IPAT model, Dietz and Rosa (1994) reformulated the basic model in stochastic terms.

[2] Ehrlich and Holdren (1970, 1972) were first with the idea of IPAT, while Commoner (1971) and Commoner, Corr, and Stamler (1971) were first with its algebraic formulation and its application to data analysis.

The resulting model, named STIRPAT (for *ST*ochastic *I*mpacts by *R*egression on *P*opulation, *A*ffluence, and *T*echnology [Rosa and Dietz 1998]), has been used successfully to estimate national $CO_2$ emissions (Dietz and Rosa 1997) and the emission of other pollutants (Rosa, York, and Dietz 2001). Unlike IPAT, the STIRPAT model is not an accounting equation, but can be used to test hypotheses and develop a more sophisticated and subtle analysis than can be done with the original $I = PAT$ formulation. The specification of the STIRPAT model is:

$$I_i = aP_i^b A_i^c T_i^d e_i. \quad (2)$$

The constant $a$ scales the model; $b$, $c$, and $d$ are the exponents of $P$, $A$, and $T$; and $e$ is the error term (the IPAT model in equation 1 assumes $a = b = c = d = e = 1$). The subscript $i$ indicates that these quantities ($I$, $P$, $A$, and $T$) vary across observational units. For hypothesis testing in an additive regression model, all factors are converted to natural logarithms. $T$ is typically included in the error term, rather than being estimated separately, as there is no clear consensus on valid technology indicators (below, we disaggregate $T$ by including additional factors in the model that can be conceptualized as influencing impact per unit of consumption). These modifications yield the following model:

$$\ln(I) = a + b[\ln(P)] + c[\ln(A)] + e. \quad (3)$$

In this model, $a$ and $e$ are the natural logarithms of $a$ and $e$ in equation 2 above. In log form, the driving force coefficients ($b$ and $c$) indicate the percentage change in $I$ in response to a 1-percent change in the driving force, with other factors held constant. This is similar to elasticity models commonly used in economics (York, Rosa, and Dietz 2001). Also, this model allows the addition of sociological or other control factors by entering them into the basic formula (equation 3), although care should be taken to ensure that additional factors are conceptually consistent with the multiplicative specification of the model. Similar to the interpretation of elasticity coefficients in economics, if STIRPAT coefficients ($b$ and $c$) equal 1.0, impact has a proportional relationship to the driving force ($P$ or $A$). Values greater than 1.0 indicate that impact increases more rapidly than the driving force; values less than 1.0 (but greater than 0) indicate that impact increases less rapidly than the driving force. Negative coefficients are mathematically possible, and some theories imply them.

The inclusion of quadratic or other polynomial versions of the logarithms of the driving forces in the model, when it is theoretically appropriate, can complicate the straightforward interpretation of the STIRPAT coefficients (Dietz and Rosa 1997). Nevertheless, a quadratic version of some variables is appropriate for testing the expectations of certain environmental impact theories, specifically those that predict a nonmonotonic relationship between impact and indicators of modernization.

## MEASURING SUSTAINABILITY

Pivotal to assessing the sustainability of societies (nations in our analysis), whether by STIRPAT or any other means, is a measure that provides a comprehensive indication of environmental impacts. There are two key considerations in the selection of a proper measure. First, because nations may import resources and export wastes (i.e., resources and wastes, and therefore ecological impacts, flow between borders) we must look beyond national borders for impacts. Therefore, focusing only on impacts within a nation (e.g., deforestation, air pollution) confounds two processes: the location of environmental impacts, and the decisions and actions that generate environmental impacts. Second, we must look at the total environmental impact of a society or nation, not simply one type of impact (e.g., forest exploitation), as one type of impact may decrease because another increases (e.g., a shift from wood to fossil fuel as a primary energy source may decrease impacts to forests but can increase emissions of pollutants) (York, Rosa, and Dietz 2002).

One measure that addresses these considerations is the "ecological footprint"[3] (Wackernagel and Rees 1996). The ecological footprint is an aggregate measure that reflects the fact that land is a basis for the

[3] For a complete description of the method used to calculate ecological footprints, see Wackernagel, Onisto et al. (1999) and Chambers, Simmons, and Wackernagel (2000).

three functional benefits provided to humans by the environment: living space, source of resources, and sink for wastes. Productive land is, therefore, a reasonable proxy for the natural capital and services provided by the environment. Calculation of the ecological footprint is based on the fact that it is possible to track most resource flows, resources consumed, and waste flows. These flow and consumption patterns can be converted into the biologically productive land areas necessary to provide these survival benefits.

The ecological footprint is calculated by "adding up the areas (adjusted for their biological productivity) that are necessary to provide us with all the ecological services we consume" (Wackernagel, Onisto et al. 1999:377). It represents the amount of biologically productive space at world average productivity, typically measured in hectares, to support the average individual in a given society. For example, a recent estimate of global productive land per capita is 2.1 hectares, while the global footprint per capita (the amount of land necessary to sustainably support an average global citizen) is approximately 2.8 hectares (Wackernagel, Onisto et al. 1999).[4] These calculations can be used as a benchmark for assessing the sustainability of all nation-states; nations with ecological footprints at or below 2.1 hectares per capita have a global impact that could be replicated by all other nations without threatening long-term sustainability if population growth were halted. Examples of recent per capita ecological footprints are 12.2 for the United States, 6.3 for Germany, 1.8 for China, and .6 (the lowest) for Bangladesh (Wackernagel, Linares et al. 2000).

One strength of using the ecological footprint as a measure of impact is that it accounts for impacts wherever they occur geographically. Another strength is that it provides a common unit of measurement (productive land area) for comparing diverse types of impacts. There are six types of productive areas that are aggregated to arrive at the total ecological footprint: (1) cropland, (2) grazing land, (3) forest, (4) fishing ground,[5] (5) built-up land, and (6) the land area required to absorb carbon dioxide emissions from the use of fossil fuel.[6] By combining diverse impacts into a single indicator, the ecological footprint does not ignore trades-offs between different types of impacts.[7]

Although it includes many types of impacts, the ecological footprint does not include all impacts. For example, pollution from hazardous substances and waste from

[4] It is possible for the total global footprint to temporarily exceed the available productive land area because some resources are being extracted faster than they are being replenished (e.g., forest products). Furthermore, the footprint includes the amount of land necessary to absorb carbon dioxide emissions. Currently, carbon dioxide emissions are in excess of biological sequestration, therefore carbon dioxide is accumulating in the atmosphere, and our total footprint (including our fossil fuel footprint) exceeds the available productive capacity of the earth.

[5] It may strike some readers as odd to include water area in the ecological footprint because water volume may seem to be a more appropriate indicator of biological productivity. However, solar energy is the basic source of biological productivity, and the amount of solar energy input depends on surface area, not volume (Chambers et al. 2000; Wackernagel and Rees 1996; Wackernagel, Onisto et al. 1999).

[6] The components of the ecological footprint include a weighting system to take into account the fact that different types of land vary in productivity. The ecological footprint for each type of land is scaled to its productivity relative to the worldwide average productivity of all land (including water). For example, arable land is more productive than other types of land, therefore, an amount of consumption requiring one hectare of arable land would have an ecological footprint larger than one hectare, reflecting the productivity of arable land relative to the average productivity of all land on earth. Built-up land is treated as arable land because cities have historically developed in agriculturally rich areas.

[7] The ecological footprint is well-regarded in scientific and environmental circles, but it is not without criticism. Van den Bergh and Verbruggen (1999) have questioned whether different types of resource consumption, and particularly land needed to absorb $CO_2$, can be appropriately combined into a single indicator based on estimates of the productive land area (weighted by biological productivity) required to produce the resources consumed. Nevertheless, many researchers from a variety of fields defend the methodology and usefulness of the ecological footprint, and it remains widely regarded as the best available comprehensive indicator of environmental impact (Ferguson 2002).

nuclear energy generation are not included in the ecological footprint. Furthermore, the ecological footprint is an indicator of anthropogenic *pressure* on the environment, not the actual consequences of that pressure (i.e., it does not directly measure deforestation, species extinction, climate change, etc., but rather the factors that generate these problems, such as the consumption of wood and crops and the combustion of fossil fuel). The validity of the ecological footprint is supportable on empirical grounds. The national ecological footprint is highly correlated with other key environmental impacts, such as national emissions of ozone depleting substances ($r = .78$) and nuclear power generation ($r = .74$).[8]

## ENVIRONMENTAL IMPACT THEORIES: THREE PERSPECTIVES

We now have a robust analytic framework (STIRPAT) and a comprehensive impact measure (the ecological footprint) for assessing the variety of environmental impact theories. We begin that assessment with a synopsis of three major theoretical perspectives: human ecology, modernization, and political economy.

### HUMAN ECOLOGY

Human ecology applies ecological principles to the understanding of human societies (Freese 1997a, 1997b). Human ecologists argue that although the capacity for technology, organization, and culture distances humans from other species, this unique capacity is always bounded by the limits imposed by ecological conditions. Hence, human ecologists emphasize an ecological foundation for understanding the driving forces of anthropogenic environmental impacts, with the expectation that key social and political variables may mediate, and perhaps partially counteract, those impacts but will not fundamentally overcome them.

Consistent with a neo-Malthusian perspective, human ecologists stress the importance of population size, growth, density, and structure for explaining environmental impacts (Catton 1980; Dietz and Rosa 1994; Duncan 1959, 1961, 1964; Harrison 1993). Human ecology also incorporates biophysical factors, such as climate and biogeography, as contexts in which social factors drive environmental impacts (Diamond 1997; Dietz and Rosa 1994; Duncan 1959, 1961, 1964; Freese 1997a, 1997b; Harris 1971, 1979; Harrison 1993; Hawley 1950, 1986; Richerson and Boyd 2000; Rosa and Dietz 1998). Human ecology suggests that climate may play an important role in influencing patterns of geographic and economic development in ways that are consequential for understanding environmental impacts.

### ECOLOGICAL MODERNIZATION: ECONOMY, DEMOCRACY, AND THE STATE

**ECONOMIC MODERNIZATION.** Environmental economists from the neoclassical tradition, while acknowledging that economic development has generated environmental problems, argue that further economic development can solve these problems rather than adding to them (Grossman and Krueger 1995). Environmental quality is assumed to be a luxury good, affordable and of interest only to affluent societies. Government and business are expected to become concerned with, and have the means for protecting, the environment once a certain level of affluence is obtained. When the requisite affluence is reached, public concern, pressure by nongovernmental organizations (NGOs), and government policies will make the mitigation of environmental problems cost-effective and will lead business to invest in environmental protection (e.g., the development of "green" technologies). The expected consequence of

[8] Data on nuclear power generation are from World Resources Institute (WRI) (2000); data on ozone-depleting substances are from Prescott-Allen (2001). These correlations are significant at an alpha level of $p < .001$. Also note that the ecological footprint correlates very strongly ($r = .99$) with national $CO_2$ emissions (data from WRI 2000). This very high correlation between the ecological footprint and $CO_2$ emissions is not surprising, as a large component of the ecological footprint is derived from fossil energy consumption. Indeed, 49 percent of the total global ecological footprint is accounted for by land necessary to absorb $CO_2$ emissions. However, if the fossil energy component of the ecological footprint is removed, the ecological footprint is still very highly correlated ($r = .94$) with $CO_2$ emissions.

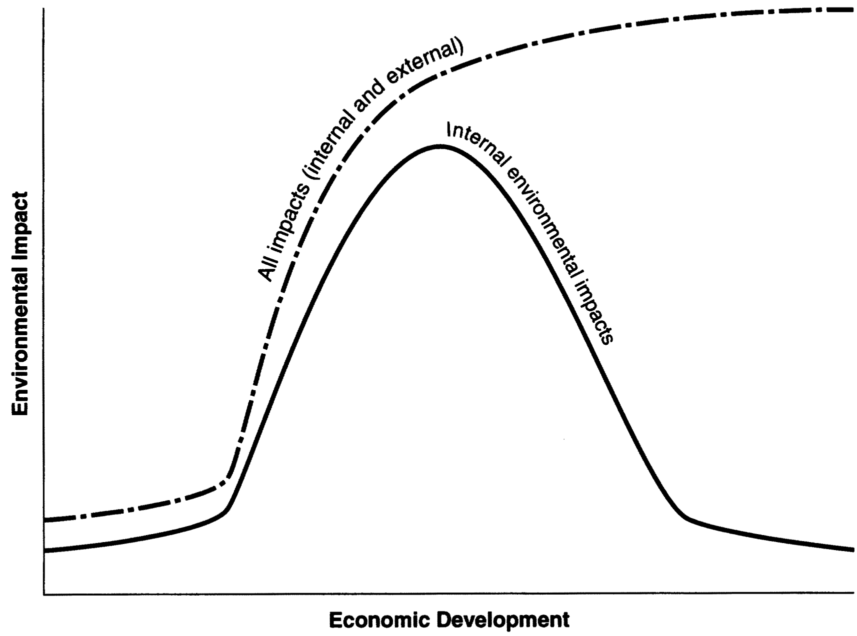


**Figure 1. The Theoretical Effect of Economic Development on Environmental Impact**

this process is a decline in environmental impacts. The primary factors that hinder this process are restrictions on free markets. Therefore, from this perspective, economic modernization (i.e., the development of free markets and economic growth) is key to solving environmental problems.

This perspective suggests that the relationship between economic development and environmental impacts may produce an inverted-U shaped curve (the solid line in Figure 1)—in other words, impacts increase in early stages of development, but level off and then decline as economies mature (Grossman and Krueger 1995). This proposed relationship between economic development and environmental impacts is known as the environmental Kuznets curve, named for economist Simon Kuznets (1955) who demonstrated this type of relationship between economic growth and income inequality.[9]

Neoclassical economic reasoning also suggests other structural factors that may lead to the reduction of environmental impacts in developed nations. The shift occurring away from manufacturing economies and toward service economies is commonly identified as a potential solution to environmental problems, because service economies are presumed to be less dependent on natural resources than are industrial economies (Organization for Economic Co-operation and Development [OECD] 1998).[10] Some have even suggested that capitalism itself may lead to environmental improvement on the assumption that, in capitalist economies, business has a strong incentive to invest in research and development that can lead to technological innovations (Samuelson and Nordhaus 1992; Simon 1981, 1996). In controlled economies, no such incentive exists as inventors do not necessarily profit from their inventions. Capitalist nations, then, should be at the forefront of developing environmentally benign or even ameliorating technologies because such technologies are potentially highly profitable.

[9] Nordström and Vaughan (1999) and Stern (1998) provide summaries of environmental Kuznets curve theory and research. *Ecological Economics* (vol. 25, no. 2, 1998) published a special issue on the environmental Kuznets curve, which provides a diversity of perspectives on the issue.

[10] Salzman (2000) presents empirical evidence contradicting this expectation.

***Ecological modernization theory.*** Ecological modernization theory[11] was developed by sociologists and makes predictions similar to those of neoclassical economists. It is not, however, as economically deterministic as the economic modernization perspective, focusing rather on the restructuring of institutions that accompanies modernization. The theory seeks to explain the dynamics and effects of modernization on the environment. Its theorists argue that, contrary to what many environmentalists and neo-Marxists claim, advanced capitalism and the institutions of modernity are not in fundamental conflict with the environment (Christoff 1996; Cohen 1999; Hajer 1995; Mol 1995, 2001; Mol and Sonnenfeld 2000; Mol and Spaargaren 2000; Sonnenfeld 1998; Spaargaren 1997; Spaargaren, Mol, and Buttel 2000). Although agreeing that modern societies have caused substantial environmental problems in the past, ecological modernization theory argues that further modernization can solve those problems as nation-states and industrial firms come to recognize the importance of environmental sustainability to their long-term survival.

A central tenet of the theory is that modernization will lead industry to become more *ecologically* rational, that is, to weigh the costs and benefits of ecological disruption and take steps to minimize environmental externalities, just as modernization also drives industry to be more economically rational (Mol 1995). Thus, ecological modernization theory proposes that as industrial processes mature, ecological impacts may decrease dramatically as production systems are restructured along ecologically rational lines. Institutional restructuring, technological innovation, market forces, the efforts of new social movements (NSMs), and government regulation are the factors that drive this process. Hence, according to ecological modernization theory, in modern industrial societies further modernization is necessary to reduce environmental impacts. The theory suggests that substantial changes in the human relationship to the environment, which are necessary to avert an ecological crisis, can occur without restructuring all aspects of society, as proposed by neo-Marxists. Through the "refinement of production," *superindustrialization* can come about, in which production systems become extremely efficient, minimizing environmental impacts (Mol 1995).

***Democracy and the state.*** Governments are often important actors that influence the emergence of ecological reforms (Goldman 2001; Mol and Spaargaren 2000). Ecological modernization theory, like some versions of the environmental Kuznets curve theory, assumes that state environmentalism and subsequent policy efforts can lead to a "greening" of production.[12] Furthermore, the efforts of NSMs, NGOs, and concerned individuals are often identified as key forces driving industry and government to address ecological problems (Mol 1995, 2001; Mol and Sonnenfeld 2000; Sonnenfeld 1998; Spaargaren et al. 2000).[13] Hence, political freedom and civil liberties are expected to lead to environmental reforms because they provide a context in which NSMs, NGOs, and individuals can influence policy and institutional behavior.

***Summary of the modernization perspective.*** While there are some differences across theorists, the key assumption of the modernization perspective is that global environmental problems can be solved through existing and/or slightly modified social, political, and economic institutions, without renouncing economic growth, capitalism, and globalization. In fact, the modernization perspective suggests that further development and modernization may alleviate environmental problems rather than adding to them.

---

[11] German theorist Joseph Huber is generally considered the founder of ecological modernization theory (Mol and Spaargaren 2000). However, the theory has grown and changed substantially because of the input of other theorists.

[12] The "world civil society" perspective makes similar assumptions regarding the potential for state environmentalism to mitigate environmental impacts (Frank, Hironaka, and Schofer 2000).

[13] Beyond our consideration here is a social structural version of environmental impact theory, the "reflexive modernization" of European theorists Ulrich Beck ([1986] 1992, [1991] 1995, 1997) and Anthony Giddens (1990, 1991, [1999] 2000) that makes arguments similar to ecological modernization theory regarding the potential for political freedom and individual rights to spur ecological reforms.

In addition to economic development (usually measured as GDP per capita), one important indicator of modernization used by ecological modernization theorists is urbanization because it is associated with many of the institutions of modernity (Ehrhardt-Martinez 1998, 1999; Ehrhardt-Martinez, Crenshaw, and Jenkins 2002; Kasarda and Crenshaw 1991). Furthermore, the rise of the service economy, the expansion of political rights and civil liberties, and state environmentalism are all expected to help curb environmental impacts.

### THE POLITICAL ECONOMY PERSPECTIVE

The political economy perspective, as applied to the environment, argues that environmental exploitation is driven by the structure of market economies, the institutions of modernity, and the relentless commitment to growth inherent in modern, particularly capitalist, production systems (O'Connor 1988; Roberts and Grimes 2002; Schnaiberg 1980). Schnaiberg and Gould (Schnaiberg 1980; Schnaiberg and Gould 1994), and O'Connor (1988, 1994, 1998) are the most widely recognized advocates of this position in sociology, although it was first clearly articulated by Anderson (1976). The political economy perspective, in the form of world-system theory, has also been applied to the global economy, rather than simply national economies, providing further insights into the factors that generate environmental impacts (Roberts and Grimes 2002).

***THE TREADMILL OF PRODUCTION AND THE SECOND CONTRADICTION OF CAPITALISM.*** For Schnaiberg and Gould (Schnaiberg 1980; Schnaiberg and Gould 1994) the "treadmill of production" is the driving force behind modern economies—and ultimately environmental impacts as well. To maintain profits, producers must constantly seek to expand production. Seeking to expand production while lowering costs, producers invest in economically efficient technologies that have higher yields per unit of labor. This results in the displacement of "costly" workers, and the only way to absorb the displaced workers is to further expand production. Workers, seeking to avoid unemployment, are trapped into supporting the increased production necessary to compensate for the increase in worker productivity. Governments, too, support increased production because it increases tax revenues, thereby providing them with the means to fund social and environmental policies. Through the continual expansion of production, the treadmill increases environmental impacts by placing greater demands on resources and by producing greater volumes of waste.

Schnaiberg (1975, 1980), then, identifies a fundamental conflict: the dialectic between society and the environment—between economic production and ecosystems. Contrary to ecological modernization theory, Schnaiberg argues that producers will not willingly internalize the environmental costs of production because doing so would reduce profits, the primary concern of producers. Furthermore, because of the political power of the economic elite, reform-oriented social and political action is unlikely to substantially alter the power of producers or to reduce environmental externalities. From the treadmill perspective, the only solution to the "enduring conflict" (Schnaiberg and Gould 1994) between society and the environment is to radically restructure society so as to limit the hegemony of producers.

O'Connor (1988, 1994, 1998), after Marx ([1867] 1967) and echoing the work of Schnaiberg and colleagues, argues that modern production economies, particularly capitalist ones, are growth dependent. Producers continually seek to reduce the costs of production, especially by reducing labor costs with improved technology. This leads to unemployment and, concomitantly, to a decline in the number of consumers with incomes to purchase the goods produced. The result is the first contradiction of capitalism: a demand crisis in which production and consumption are unbalanced.

One potential route out of this crisis is to expand markets. However, expansion is limited because the number of markets is bounded and natural resources are ultimately finite. This leads to O'Connor's (1988, 1994) second contradiction of capitalism: Escalating production depletes the natural resources required to sustain production, which escalates costs and results in shrinking profits. The continued depletion of resources can lead to an environmental crisis, as nature's capital and services are lost.

The fundamental assumption of the political economy perspective is that economic production is in fundamental conflict with ecological limits. The only way to prevent further ecological deterioration is to curb economic growth in its traditional form. Technology that improves the efficiency of resource use, superficially appearing to reduce environmental impacts, only serves to ultimately increase impacts because the resulting increased profits are inevitably reinvested to increase production (often in a different industry or firm) and thereby accelerate growth and expand impacts.[14] This is a point often missed by ecological modernization theorists: The political economy perspective focuses on economy-wide impacts, not necessarily on the impacts of any one industry or firm. From a political economy perspective, ecological modernization theorists (e.g., Mol 1995; Sonnenfeld 1998) are typically using the wrong unit of analysis when they focus on transformations in a single industry.

***WORLD-SYSTEM THEORY.*** World-system theory applies the logic of the neo-Marxist political economy perspective at a global scale and has recently extended its reach to examine environmental impacts (Bunker 1984, 1985; Burns et al. 1994; Kick et al. 1996; Roberts and Grimes 2002). The central point of world-system theory is that all nations of the world are organized into a single global economy that is dominated economically, politically, and militarily by wealthy nations (Wallerstein 1974). The theory sees nations as divided roughly into three basic structural locations: core, semiperiphery, and periphery. Wealthy influential nations, such as the United States, Japan, and most western European nations, are the core nations that largely control trade relationships with other nations and dominate politics. Peripheral nations, such as most nations in sub-Saharan Africa, have small, typically minimally industrialized, economies and lack global political power. Semiperipheral nations, such as emerging economies like Brazil and Mexico, occupy a position of intermediate power relative to the core and the periphery.

Consistent with the political economy perspective, world-system theory identifies economic production as the primary driving force behind environmental impacts. However, the theory adds a key point: Core nations are the predominant global producers and consumers, but they extract the basic resources they need for production (e.g., timber, minerals) from, and export (often hazardous) waste to, peripheral nations (Bunker 1984, 1985; Frey 1994, 1995, 1998a, b). Thus, for world-system theory, evidence demonstrating an environmental Kuznets curve of reduced environmental impacts in core nations via ecological modernization is spurious. Indeed, Roberts and Grimes (1997) have shown that, for carbon dioxide emissions, the overall pattern of an environmental Kuznets curve can be explained by nations at different positions in the world-system being locked into different trajectories of fossil fuel use. Evidence of an environmental Kuznets curve typically has been found only for local impacts, which calls into question whether development ultimately reduces impacts or simply shifts them elsewhere (Nordström and Vaughan 1999; Rothman 1998; Stern 1998). The assumption that impacts are geographically coterminous with the populations causing them is fundamentally flawed—an example of the "Netherlands fallacy"[15]

[14] That improvements in efficiency increase resource use is known as the "Jevons Paradox" (Clark and Foster 2001). Jevons ([1865] 2001) observed that increases in the efficiency of coal use did not lead to decreases in coal consumption, but rather, increased the total amount of coal consumed because greater efficiency made coal use more cost effective and therefore more desirable to industrial consumers as a fuel source. This argument is supported by Bunker's (1996) finding that, historically, resource efficiency has steadily improved (i.e., resource use per unit of production has decreased), while total resource use has continually increased because economic expansion has outstripped improvements in efficiency. From this perspective, then, "green" technology offers no real solution—while it may reduce the impact per unit of production, it cannot keep pace with increases in the volume of production that eventually outstrip any savings from improvements in efficiency.

[15] The term refers to the fact that the Netherlands imports most of its resources, and therefore its national environmental impacts extend well beyond its borders.

(Ehrlich and Holdren 1971). Similar to Rothman's (1998) argument, world-system theory argues that core nations have the power to distance themselves from the impacts they generate, and it is, therefore, misleading to focus only on the impacts a society generates within its national borders.

The general logic of world-system theory argues that a focus on *total* impacts, those generated within and beyond national borders, is essential to a theoretical understanding of threats to sustainability. The political economy perspective anticipates that environmental impacts will continually increase with economic growth, but will not occur entirely within the borders of the nations generating the economic growth. The dotted curve in Figure 1 illustrates this expectation—a clear contrast with the environmental Kuznets curve hypothesis.

***SUMMARY OF THE POLITICAL ECONOMY PERSPECTIVE.*** The political economy perspective identifies economic growth as the key driving force behind environmental impacts. Although this tradition emphasizes the inherent anti-ecological nature of capitalistic growth, the arguments can be generalized to include all modern growth-dependent production economies. The fundamental point is that technological development and reform-oriented policy will not solve the problem of environmental degradation. The fundamental solution rests on a restructuring of societies away from economic expansion and toward ecological sustainability.

## DATA AND ANALYSIS

We are now in a position to assess our selected environmental impact theories by mapping their variables into the STIRPAT framework.

### *VARIABLES*

For our independent and dependent variables we use 1996 data (see Table 1 for data sources and variable descriptions) where available—as it is for most variables, including the ecological footprint, for most nations—and substitute earlier data or interpolate values by averaging values for other years where necessary. Note that all variables are in a form conceptually appropriate for the multiplicative specification of the STIRPAT model. All continuous variables are in natural logarithmic form. Variables that are difficult to interpret in logarithmic form or otherwise do not fit the multiplicative model in their original units are coded to a series of dummy variables. Dummy variables are easy to interpret in the STIRPAT model—the antilog ($e^x$) of the coefficient for the dummy variable is the multiplier when the variable is coded 1, relative to when the variable is coded 0.

***HUMAN ECOLOGY VARIABLES.*** We use *population* size and the percentage of the population aged 15 to 65 (i.e., the *non-dependent population*) to assess neo-Malthusian and human ecological predictions. We use the predominant *latitude* of a nation and *land area per capita* (the inverse of density) to control for basic climate and biogeography.

***MODERNIZATION VARIABLES.*** We use *GDP per capita* as the indicator of economic development, and the *quadratic of GDP per capita* (centered before squaring) to allow for a nonmonotonic relationship between development and impacts. As an indicator of economic structure, we include the *percentage of GDP not in the service sector* to test for predictions regarding the purported ameliorating effect on impacts of a shift to a service economy. We use the *percentage of the population living in urban areas* as a general indicator of modernization, and the *quadratic of the percentage of the population living in urban areas* (centered before squaring) to allow for a nonmonotonic relationship as predicted by some modernization theorists (Ehrhardt-Martinez 1998; Ehrhardt-Martinez et al. 2002).

To assess predictions from ecological modernization theory regarding the effects of neoliberal political freedoms, we use indicators for both *political rights* and *civil liberties*, each of which we code into three dummy variables, because it is not necessarily reasonable to assume that impacts are a straightforward multiplicative function of a variable measured on an ordinal scale. To assess expectations about the effects of state commitment to environmental protection, we use an indicator of *state environmental-*

**Table 1. Description of the Variables Used in the Analysis**

| Variable | Description | Transformation | Data Source |
|---|---|---|---|
| *Dependent Variable* | | | |
| Ecological footprint | Land area in hectares required to support consumption of nation-state (1996). | Logged. For five cases, one or two of the six components of the total ecological footprint were imputed (because they were missing). | Wackernagel, Linares, et al. (2000) |
| *Independent Variables* | | | |
| Population | 1996 population (1000s). | Logged. | United Nations Population Division (1998) |
| Nondependent population | Percentage of population aged 15–65 (1995). | Logged. | WRI (1996) |
| Land area per capita | Land area in hectares per capita. | Logged. | WRI (1998) |
| Latitude | Distance from equator as indicator of climate. | Dummy variables coded into three categories based on the predominant latitude of nation: arctic (> 55 degrees), temperate (30–55 degrees), and tropical (< 30 degrees). Tropical is the reference category. | Espenshade (1993) |
| GDP per capita | Per capita gross domestic product in purchasing power parity (1996). | Logged. Interpolated from 1995 and 1997 values. | WRI (1998, 2000) |
| Quadratic of GDP per capita | [log (*GDP per capita*) – Mean]$^2$ | The log of GDP per capita centered by subtracting the mean of the log of GDP per capita and then squared to reduce collinearity with GDP per capita. | WRI (1998, 2000) |
| Percentage non-service GDP | Percentage of GDP not in service sector (1996). | Logged. Interpolated from 1995 and 1997 values. The values for three cases were imputed based on values of other independent variables. | WRI (1998, 2000) |
| Capitalist nation | Dummy variable. | If nation is reported as "capitalist," "mixed-capitalist," or "capitalist-statist," then the variable equals 1; otherwise it equals 0. | Freedom House (1997) |
| Percentage urban | Percent of population living in urban areas (1995). | Logged. | WRI (1996) |
| Quadratic of percentage urban | [log (*Percentage urban*) – Mean]$^2$ | The log of percentage urban centered by subtracting the mean of the log of percentage urban and then squared to reduce collinearity with percentage urban. | WRI (1996) |
| World-system position | Estimate based on the amount of "official development assistance" and "official assistance" a nation gives or receives (1995–1997). | Dummy variables coded into three categories: core = nations that are not net recipients of assistance; semi-periphery = nations that are net recipients but the assistance is less than .5 percent of their GDP; and periphery = all other nations. Periphery is the reference category. | WRI (2000) |

*(Continued on next page)*

*(Table 1 continued from previous page)*

| Variable | Description | Transformation | Data Source |
|---|---|---|---|
| *Independent Variables (Continued)* | | | |
| Political rights | Reflects whether a nation is governed by democratically elected representatives and has fair, open, and inclusive elections (1996). | Dummy variables coded into three categories based on original 7-point scale: free (1–2), partially free (3-5), or not free (6–7). Not free is the reference category. | Freedom House (1997) |
| Civil liberties | Reflects whether within a nation there is freedom of the press, freedom of assembly and demonstration, general personal freedoms, freedom of private organizations (including businesses), and property rights (1996). | Dummy variables coded into three categories based on original 7-point scale: free (1–2), partially free (3-5), or not free (6–7). Not free is the reference category. | Freedom House (1997) |
| State environmentalism | Index based on state's participation in 16 environmental treaties. | Dummy variables coded on dividing the index into equal thirds reflecting degree of environmentalism: high, medium, and low (reference category). | Roberts and Vásquez (2002) |

*ism* (coded into dummy variables) based on participation in environmental treaties.[16]

**POLITICAL ECONOMY VARIABLES.** The most important variable for assessing the predictions of the "treadmill of production" is *GDP per capita.* As an indicator of political economy, we include a dummy variable indicating whether a nation is predominantly *capitalist* (political economic and modernization theories predict opposite signs for this variable). As an indicator of *position in the world-system* (i.e., dependency status), we use official development assistance and official assistance to generate three dummy variables: core nations, semiperipheral nations, and peripheral nations.[17]

## ANALYSIS

We apply the STIRPAT model using ordinary-least-squares (OLS) regression to examine the effect of theoretically relevant variables on the ecological footprint. We include in our sample all nations for which requisite data could be obtained—a total of 142 nations (see Table 2)—which contain more than 97 percent of the world's population and economic output. We look at six models: Model 1, the saturated model, which includes all independent variables; Model 2,

[16] The indicator we use, developed by Roberts and Vásquez (2002), is an updated version of the index developed by Dietz and Kalof (1992).

[17] For indicators of world-system position, we considered using, in addition to official development assistance and official assistance, total external debt. We do not use total external debt because data are missing for an unacceptably high number of nations (32), most of which are developed nations. Official development assistance and official assistance as a percentage of GDP is available for all nations in our sample, has a moderately strong correlation with total external debt as a percentage of GDP ($r = .53$, N = 110, $p < .001$), and breaks nations into world-system categories that are consistent with other analyses. For example, a three-point ordinal variable (core, semiperiphery, periphery) generated from the official development assistance and official assistance as percentage of GDP (which we used to generate our dummy variables) is highly correlated ($r = .74$, N = 96, $p < .001$) with Snyder and Kick's (1979) codings as modified by Bollen (1983) on the same three-point scale. Also, we note that using total external debt as the world-system position indicator does not substantively alter our results.

**Table 2. Nations in the Sample (N = 142), Including the Antilog of Residuals for Model 4 (Table 3)**

| Country | Antilog | Country | Antilog | Country | Antilog | Country | Antilog |
|---|---|---|---|---|---|---|---|
| Albania | .92 | Egypt | 1.05 | Lebanon | .79 | Senegal | .90 |
| Algeria | .62 | El Salvador | 1.12 | Lesotho | 1.22 | Sierra Leone | .88 |
| Angola | .82 | Eritea | .82 | Lithuania | 1.28 | Singapore | 1.89 |
| Argentina | .76 | Estonia | 1.72 | Macedonia | 1.09 | Slovakia | 1.15 |
| Armenia | .69 | Ethiopia | 1.24 | Madagascar | 1.11 | Slovenia | .98 |
| Australia | .95 | Finland | 1.08 | Malawi | 1.17 | Somalia | 1.11 |
| Austria | .80 | France | 1.05 | Malaysia | 1.37 | South Africa | 1.35 |
| Azerbaijan | 1.12 | Gabon | .88 | Mali | 1.05 | Spain | .86 |
| Bangladesh | .69 | Gambia | .97 | Mauritania | .81 | Sri Lanka | .65 |
| Belarus | 1.52 | Georgia | .73 | Mauritius | .71 | Sudan | 1.17 |
| Belgium | .68 | Germany | .83 | Mexico | .93 | Sweden | .93 |
| Benin | 1.00 | Ghana | 1.05 | Moldova Rep. | 1.07 | Switzerland | .87 |
| Bhutan | .75 | Greece | 1.05 | Mongolia | 1.87 | Syria | 1.28 |
| Bolivia | .71 | Guatemala | .97 | Morocco | .68 | Tajikistan | .73 |
| Botswana | .77 | Guinea | .95 | Mozambique | .85 | Tanzania | 1.32 |
| Brazil | .91 | Guinea Bissau | .87 | Myanmar | 1.16 | Thailand | 1.17 |
| Bulgaria | 1.11 | Haiti | .81 | Nepal | 1.14 | Togo | .86 |
| Burkina Faso | 1.04 | Honduras | 1.12 | Netherlands | .79 | Trinidad/Tobago | .78 |
| Burundi | 1.00 | Hungary | 1.25 | New Zealand | 1.26 | Tunisia | .75 |
| Cambodia | .89 | Iceland | .52 | Nicaragua | .90 | Turkey | .84 |
| Cameroon | .70 | India | 1.02 | Niger | 1.18 | Turkmenistan | 1.59 |
| Canada | .80 | Indonesia | .88 | Nigeria | 1.44 | Uganda | 1.09 |
| Cent. Afr. Rep. | .95 | Iran | .98 | Norway | .69 | Ukraine | 1.89 |
| Chad | .79 | Ireland | 1.50 | Oman | 1.61 | United Arab Emirates | 2.76 |
| Chile | .61 | Israel | .87 | Pakistan | 1.09 | | |
| China | .89 | Italy | .81 | Panama | .88 | United Kingdom | .90 |
| Colombia | .60 | Jamaica | 1.29 | Papua New Guinea | .96 | United States | 1.46 |
| Congo Dem. Rep. | .92 | Japan | .78 | Paraguay | 1.48 | Uruguay | .99 |
| Congo Rep. | .80 | Jordan | .74 | Peru | .56 | Uzbekistan | 1.50 |
| Costa Rica | 1.17 | Kazakhstan | 1.52 | Philippines | .90 | Venezuela | .82 |
| Côte d'Ivoire | .91 | Kenya | 1.31 | Poland | 1.53 | Vietnam | .92 |
| Croatia | .65 | Korea Republic | .98 | Portugal | 1.08 | Yemen | .80 |
| Czech Rep. | 1.30 | Kuwait | 1.95 | Romania | 1.13 | Yugoslavia | 1.14 |
| Denmark | 1.16 | Kyrgyzstan | 1.02 | Russia | 1.32 | Zambia | 1.20 |
| Dominican Rep. | .64 | Laos | .88 | Rwanda | 1.07 | Zimbabwe | 1.18 |
| Ecuador | 1.03 | Latvia | 1.03 | Saudi Arabia | 1.86 | | |

the modernization model, which excludes world-system position indicators, latitude, and land area per capita; Model 3, the political economy model, which excludes latitude, land area per capita, political rights, civil liberties, state environmentalism, and the percentage of the economy not in the service sector; Model 4, the human ecology model, which includes only the basic material conditions variables; Model 5, the quadratic STIRPAT model; and Model 6, the two-factor basic STIRPAT model.

## RESULTS AND DISCUSSION

The OLS regression results for all six models are presented in Table 3.[18] Model 1, the saturated model, clearly provides a good fit, explaining over 97 percent of the cross-national variance in the ecological footprint.[19] Although there are many variables in the model, problems with multicollinearity are not dramatic—the highest VIF for any variable is 8.55, which is clearly within generally accepted guidelines (Chatterjee, Hadi, and Price 2000). The coefficients for basic material factors (population size and age structure, GDP per capita, urbanization, latitude, and land area per capita) stand out as clearly significant, while all other factors have nonsignificant effects. The coefficient for quadratic of per capita GDP is significant, but the value is positive—opposite of that necessary to generate an environmental Kuznets curve.

Model 2, the modernization model, yields similar conclusions. The only changes of note are that the coefficient for the quadratic of GDP per capita becomes nonsignificant, and the coefficient for the quadratic of urbanization becomes significant (but in the opposite direction predicted by modernization theorists).

Model 3, the political economy model, suggests a conclusion similar to the saturated model. However, the coefficient for the capitalist variable is significant and in the direction expected by modernization theorists. The antilog of the coefficient for the capitalist variable ($b = -.165$) equals .85, which indicates that environmental impacts in capitalist nations are 85 percent of (or 15 percent lower than) those of noncapitalist nations, other factors held constant.

The human ecology model (Model 4), more parsimonious than Models 1 and 2, explains a greater proportion of the variance than all other models except Model 1, and fits the data as well as Model 1 ($F[10,123] = 1.31$, which is not significant even at the .10 alpha level).

Models 5 and 6 are the most parsimonious and fit the data remarkably well considering their minimal specification. But, because all the additional factors in Model 4 are significant, Models 5 and 6 provide a less than complete explanation of national ecological footprints.

We focus our interpretation on Model 4: It is more parsimonious than the saturated model (Model 1) but also explains virtually the same amount of variance. Model 4 includes all factors that have significant coefficients in the other models with the exception of the capitalist variable, which is significant only in Model 3. If the ecological factors (latitude and land area per capita) are added to Model 3, the coefficient for capitalism is no longer significant. Likewise, if capitalism is added to Model 4, it has a nonsignificant effect. The indication is, therefore, that it is the ecological factors, not capitalism directly, that principally influence impacts.

Population size has a roughly proportional effect on the ecological footprint—the coefficient indicates that a 1-percent increase in population size leads to an increase in the ecological footprint of .98 percent, with other factors held constant (note that all following interpretations also refer to all-else-equal conditions). This population coefficient is remarkably stable across all six models and is in fact not significantly different from 1.0 in any model. The age structure

[18] We also ran the models using a robust (Huber/biweight) regression procedure to assess whether there were cases that had an inordinate effect on the results. We found no substantive differences between the robust results and the OLS results. We also used case-based bootstrap resampling to estimate the standard error to determine if this procedure produced substantially different results than normal theory standard error (as suggested by Dietz, Frey, and Kalof [1987] and Dietz, Kalof, and Frey [1991]). It did not, so here we present only the normal theory standard error estimates. We also calculated a series of diagnostic statistics (DFBETAS, Cooks' D) to test for influential cases and violations of OLS assumptions and found no indication of substantial problems.

[19] In models not presented here, we included the following additional variables: direct foreign investment as a percentage of GDP, total external debt as a percentage of GDP, percentage of GDP from industry, and a measure of income inequality (the ratio of the income share of the richest fifth of the population to that of the poorest fifth). These variables did not have significant effects in any models, nor did they substantively alter the coefficients of other variables.

**Table 3. OLS Coefficients Predicting National Ecological Footprint: 142 Nations circa 1996**

| | Model 1 Saturated Model | | Model 2 Modernization | | Model 3 Political Economy | | Model 4 Human Ecology | | Model 5 Quadratic STIRPAT | | Model 6 Basic STIRPAT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Independent Variables | *b* | (S.E.) | *b* | (S.E.) | *b* | (S.E.) | *b* | (S.E.) | *b* | (S.E.) | *b* | (S.E.) |
| Population (log) | .992*** | (.023) | .987*** | (.023) | .964*** | (.022) | .980*** | (.018) | .977*** | (.022) | .977*** | (.022) |
| Nondependent population (log) | 1.302** | (.467) | 1.594*** | (.425) | 1.431*** | (.390) | 1.387*** | (.426) | — | | — | |
| Land area per capita (log) | .045* | (.022) | — | | — | | .045* | (.022) | — | | — | |
| *Latitude*[a] | | | | | | | | | | | | |
| Arctic | .435** | (.136) | — | | — | | .339** | (.124) | — | | — | |
| Temperate | .283*** | (.081) | — | | — | | .260*** | (.070) | — | | — | |
| GDP per capita (log) | .455*** | (.064) | .443*** | (.056) | .430*** | (.065) | .396*** | (.042) | .658*** | (.028) | .660*** | (.028) |
| Quadratic of GDP per capita | .088** | (.032) | .050 | (.027) | .066* | (.031) | .049* | (.023) | .028 | (.026) | — | |
| Percentage nonservice GDP (log) | .005 | (.150) | .061 | (.158) | — | | — | | — | | — | |
| Capitalist nation | –.022 | (.072) | –.124 | (.072) | –.165* | (.065) | — | | — | | — | |
| Percentage urban (log) | .247* | (.095) | .405*** | (.095) | .353*** | (.093) | .280** | (.089) | — | | — | |
| Quadratic of percentage urban | .104 | (.064) | .139* | (.067) | .125 | (.066) | .139* | (.062) | — | | — | |
| *World-System Position*[b] | | | | | | | | | | | | |
| Core | –.110 | (.166) | — | | .062 | (.163) | — | | — | | — | |
| Semiperiphery | .117 | (.084) | — | | .120 | (.084) | — | | — | | — | |
| *Political Rights*[c] | | | | | | | | | | | | |
| Free | –.002 | (.106) | –.023 | (.113) | — | | — | | — | | — | |
| Partially free | –.018 | (.089) | –.074 | (.094) | — | | — | | — | | — | |
| *Civil Liberties*[c] | | | | | | | | | | | | |
| Free | –.013 | (.147) | .022 | (.157) | — | | — | | — | | — | |
| Partially free | –.020 | (.101) | –.045 | (.107) | — | | — | | — | | — | |
| *State Environmentalism*[d] | | | | | | | | | | | | |
| High | –.177 | (.096) | –.130 | (.101) | — | | — | | — | | — | |
| Medium | –.069 | (.070) | –.073 | (.074) | — | | — | | — | | — | |
| Constant | 8.958*** | (1.863) | –10.786*** | (1.631) | –9.362*** | (1.448) | –8.780*** | (1.510) | –4.246*** | (.422) | –4.233*** | (.422) |
| $R^2$ | .972 | | .966 | | .965 | | .969 | | .949 | | .949 | |
| Mean VIF/highest VIF | 3.63/8.55 | | 3.33/6.76 | | 3.32/7.74 | | 2.36/4.54 | | 1.00/1.00 | | 1.00/1.00 | |

[a] Tropical is the reference category. [b] Periphery is the reference category. [c] Not free is the reference category. [d] Low state environmentalism is the reference category.

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$ (two-tailed tests) variable (percentage nondependent population) is also positive and significant, indicating that the larger the proportion of a nation's population between the ages of 15 and 65 (the most productive ages), the larger a nation's ecological footprint. These findings support neo-Malthusian and human ecological claims regarding the importance of population for explaining environmental impacts.

The other ecological variables (latitude and land area per capita) also have significant effects. Impacts are higher in nations with more land area per capita, suggesting that resource availability and/or density influence resource demand. Impacts increase the further a nation is from the tropics. Nations in temperate regions have 30 percent greater ecological footprints (the antilog of .260 is 1.30), and nations in arctic regions have 40 percent greater ecological footprints (the antilog of .339 is 1.40) than do nations in the tropics. This finding reinforces the obvious: More resources are required to sustain societies in colder climates.

The coefficients for both GDP per capita and the quadratic of GDP per capita are positive and significant. The positive coefficient for the quadratic of GDP per capita is the opposite of what is necessary to generate an environmental Kuznets curve. The effect of GDP per capita, then, on the ecological footprint is monotonically positive within the range of observations—an increase in per capita GDP consistently leads to an increase in the ecological footprint, contradicting the expectation of the modernization perspective.[20]

Also counter to the claims of the modernization perspective, urbanization increases impacts. The coefficients for urbanization and the quadratic of urbanization are both positive, indicating that, to the degree urbanization is an indicator of modernization, modernization increases, rather than decreases, impacts.[21] This finding is fully consistent with the work of Foster (1999, 2000), who, drawing on Marx ([1867] 1967), argues that modernization, because of the separation it generates between country and city, creates a metabolic rift between ecological processes and economic processes.

The political economy perspective receives support for one of its key premises—the conflict between the economy and the environment—but other important political economy variables do not have significant effects on impacts. The results suggest that impacts are not *directly* the result of capitalism or world-system position per se, but rather are generated by more basic material conditions, which in turn may be mediated by capitalism and world-system position.

The expectations of the modernization perspective are clearly contradicted—no environmental Kuznets curve exists for either GDP per capita or urbanization, and the size of the service sector, the presence of a capitalist system, political rights, civil liberties, and state environmentalism have no significant effects on the ecological footprint.

Table 2 presents the antilog of the residuals from Model 4 for each nation in the

[20] Due to the inclusion of the quadratic term in the model, the coefficient for per capita GDP cannot be interpreted directly as an elasticity coefficient (i.e., the percentage change in the dependent variable for a 1-percent change in the independent variable). However, as York et al. (2001) show, the instantaneous elasticity coefficient can be calculated by taking the first partial derivative of the regression equation with respect to $\ln(A)$. Because the coefficient for the quadratic term is close to zero, the elasticity coefficient does not vary dramatically over the range of observations. Running Model 4 excluding the quadratic term yields a coefficient for GDP per capita of .412, which is roughly the coefficient that would be obtained for any value of $\ln(A)$ within the range of observations, using the procedure mentioned above for the model including the quadratic term. This means that a 1-percent increase in per capita GDP roughly corresponds to a .412 percent increase in the ecological footprint.

[21] Note that, because the quadratic term was centered before squaring, the coefficient for the quadratic term is large enough (just barely) to generate a U-shaped relationship (the opposite of an environmental Kuznets curve) with the ecological footprint, within the range of observations. The minimum of the curve is reached when urbanization is at approximately 16.5 percent. As urbanization increases above this value, the ecological footprint increases monotonically with urbanization. In our sample, only nine nations have values below this minimum, therefore, in almost all cases we would expect an increase in urbanization to correspond with an increase in the ecological footprint.

study. These can be interpreted as nation-specific multipliers of the ecological footprint. These coefficients, in a sense, represent the eco-efficiency of a nation—the environmental impact of a nation when controlling for basic material conditions. The mean residual is 0 and its antilog is 1; therefore, nations with values below 1 are more efficient than expected based on the factors in Model 4, and those with values greater than 1 are less efficient than expected based on the model. The residuals occupy a fairly narrow range, from a low value of .52 for Iceland to a high value of 2.76 for the United Arab Emirates. This suggests that the most efficient nation is only slightly more than five times (2.76/.52 = 5.3) more efficient than the least efficient nation, and only twice as efficient as the typical nation. Therefore, given current cross-national variability in efficiency, there is some room for reducing impacts holding basic material conditions constant. However, there appears to be nowhere near the dramatic potential that some scholars suggest (e.g., Hawken, Lovins, and Lovins 1999) for reducing impacts without altering the primary driving forces (particularly population and affluence).

## CONCLUSION

We have extracted from a variety of leading social theories—human ecology, modernization, and political economy—key factors identified as driving anthropogenic (human-induced) environmental impact. From ecology we adopted and modified an analytic framework and methodological technique, the STIRPAT model, for assessing the effects of driving forces on environmental impact. We used a comprehensive measure, the ecological footprint, as an indicator of environmental impact.

We have found that impact changes proportionately with population, consistent with neo-Malthusian and human ecological arguments, and that the age structure of population influences impacts. Also consistent with the arguments of human ecologists, latitude (an indicator of climate) and per capita land area affect impacts. Consistent with arguments from political economy, and contrary to the expectations of neo-classical economists regarding an environmental Kuznets curve, increases in GDP per capita consistently lead to increases in impacts, but the increases are not proportional. Furthermore, urbanization also increases impacts, contrary to the expectation of the modernization perspective. Factors identified by ecological modernization theorists as potentially mitigating human impacts on the environment, such as state environmentalism, political rights, civil liberties, service sector development, and the presence of a capitalist system have no significant effects on impacts. Taken together, these results suggest that basic economic and ecological factors largely determine human impact on the environment.

Our results do not argue that institutional and technological changes are irrelevant to environmental impacts. Given the slow pace of population change over the span of a generation and the political pressure for economic growth, strategies for making a transition to sustainability should emphasize technologies with more benign environmental impacts. However, the sobering note from this analysis is our failure to detect the ameliorating processes postulated by neoclassical economics and ecological modernization theorists. This suggests we cannot be sanguine about ecological sustainability via emergent institutional change.

It is important to bear in mind that our estimated coefficients are exponents in a multiplicative function. Hence, whenever these coefficients are positive, any increase in an independent variable increases impacts in combination with the other factors. A key consequence is that because of high levels of consumption in affluent nations, even a slow rate of population growth in these nations is at least as great a threat to the environment as is a rapid rate of population growth in less developed nations. After all, the footprint of the typical American is nearly 25 times greater than that of the typical Bangladeshi.

So to bring complementarity to Chase-Dunn's (1998) vivid description of threats to sustainability—"[I]f the Chinese try to eat as much meat and eggs and drive as many cars (per capita) as the Americans the biosphere will fry" (p. *xxi*)—we can point out that a slow, but steady, growth in the American population, at current consumption levels, may equally challenge the biosphere. Recognizing the primacy of population, modernization, and eco-geographic factors as drivers of environmental impacts is essential if appropriate action is to be taken to address the problems of global sustainability. Current trends, rather than ameliorating problems, exacerbate them and make more urgent the search for new institutional and technological forms that can countervail or even reduce the impacts associated with growth.

At the outset, we identified two orientations in sociological theorizing about the environment: a revival of classical thinking, and a variety of environmental impact theories. Our results showing sizable and persistent effects from population and economic production, although derived from contemporary environmental impact theories, provide a link to classical theories. Marx ([1867] 1967) argued that the material conditions of production are the basic determinant of the structure of society. Durkheim ([1893] 1964) argued that unrestrained population growth, by increasing competition over ecological resources, resulted in a specialized division of labor. What Durkheim and Marx apparently could not fully see was the second-order consequence of these evolutionary processes, revealed in our results, that environmental threats to sustainability are also principally due to population growth and economic growth.

***Richard York*** *recently completed his Ph.D. at Washington State University. He is now Assistant Professor of Sociology at the University of Oregon. His research concentrates on the relationship between population, development, capitalism, and the environment. He has an article forthcoming in* Human Ecology Review *and is coauthor of "Bridging Environmental Science with Environmental Policy" (*Social Science Quarterly, *2002, vol. 83, pp. 18–34).*

***Eugene A. Rosa*** *is Professor of Sociology, the Edward R. Meyer Professor of Natural Resource & Environmental Policy, an Affiliated Professor of Environmental Science, and an Affiliated Professor of Fine Arts at Washington State University. His current research concentrates on global environmental change and on the democratization of environmental and technological decision making, with the former focus connected to his service on the National Academy of Sciences/National Research Council Committee reviewing the U.S. Climate Change Science Program and with the latter focus connected to his service on a National Academy of Sciences/National Research Council Committee on high-level nuclear waste. Recent publications include* Risk, Uncertainty, and Rational Action *(2001, Earthscan Press).*

***Thomas Dietz*** *is Professor of Sociology and Crop and Soil Science and Director of the Environmental Science and Policy Program at Michigan State University. He chairs the U.S. National Research Council Committee on Human Dimensions of Global Environmental Change. His research interests include the human dimensions of global change and the interplay between science and democracy. Recent publications include* The Drama of the Commons *(2002, National Academy Press) and* New Tools for Environmental Protection: Education, Information, and Voluntary Measures *(2002, National Academy Press).*

## REFERENCES

Anderson, Charles H. 1976. *The Sociology of Survival: Social Problems of Growth.* Homewood, IL: Dorsey.

Beck, Ulrich. [1986] 1992. *Risk Society: Toward a New Modernity.* Reprint, London, England: Sage.

———. [1991] 1995. *Ecological Enlightenment: Essays on the Politics of the Risk Society.* Translated by M. Ritter. Reprint, New York: Humanities Press.

———.1997. "Subpolitics and the Disintegration of Institutional Power." *Organization and Environment* 10:52–65.

Bollen, Kenneth. 1983. "World System Position, Dependency, and Democracy: The Cross-National Evidence." *American Sociological Review* 48:468–79.

Bunker, Stephen G. 1984. "Modes of Extraction, Unequal Exchange, and the Progressive Underdevelopment of an Extreme Periphery: The Brazilian Amazon, 1600–1980." *American Journal of Sociology* 89:1017–64.

———. 1985. *Underdeveloping the Amazon: Extraction, Unequal Exchange, and the Failure of the Modern State.* Urbana, IL: University of Illinois Press.

———. 1996. "Raw Material and the Global Economy: Oversights and Distortions in Industrial Ecology." *Society and Natural Resources* 9:419–29.

Burns, Thomas J., Edward I. Kick, David A. Murray, and Dixie Murray. 1994. "Demography, Development and Deforestation in a World-System Perspective." *International Journal of Comparative Sociology* 35:221–39.

Buttel, Frederick H. 1987. "New Directions in

Environmental Sociology." *Annual Review of Sociology* 13:465–88.

Catton, William. 1980. *Overshoot: The Ecological Basis of Revolutionary Change*. Chicago, IL: University of Illinois Press.

Chambers, Nicky, Craig Simmons, and Mathis Wackernagel. 2000. *Sharing Nature's Interest: Ecological Footprints as an Indicator of Sustainability*. London, England: Earthscan.

Chase-Dunn, Christopher. 1998. *Global Formation: Structures of the World Economy*. Updated ed. Lanham, MD: Rowman and Littlefield.

Chatterjee, Samprit, Ali S. Hadi, and Bertram Price. 2000. *Regression Analysis by Example*. 3d ed. New York: John Wiley.

Christoff, Peter. 1996. "Ecological Modernization, Ecological Modernities." *Environmental Politics* 5:476–500.

Clark, Brett and John Bellamy Foster. 2001. "William Stanley Jevons and *The Coal Question*: An Introduction to Jevons's 'Of the Economy of Fuel.'" *Organization and Environment* 14:93–8.

Cohen, Maurie. 1999. "Sustainable Development and Ecological Modernization: National Capacity for Rigorous Environmental Reform." Pp. 103–28 in *Environmental Policy and Societal Aims,* edited by D. Requier-Desjardins, C. Spash, and J. van der Straaten. Dordrecht, Netherlands: Kluwer.

Commoner, Barry. 1971. *The Closing Circle*. New York: Knopf.

Commoner, Barry, Michael Corr, and Paul J. Stamler. 1971. "The Causes of Pollution." *Environment* 13:2–19.

Diamond, Jared. 1997. *Guns, Germs, and Steel: The Fates of Human Societies*. New York: W.W. Norton.

Dickens, Peter. 1992. *Society and Nature: Toward a Green Social Theory*. Philadelphia, PA: Temple University Press.

Dietz, Thomas, R. Scott Frey, and Linda Kalof. 1987. "Estimation with Cross-National Data: Robust and Nonparametric Methods." *American Sociological Review* 52:380–90.

Dietz, Thomas and Linda Kalof. 1992. "Environmentalism among Nation-States." *Social Indicators Research* 26:353–66.

Dietz, Thomas, Linda Kalof, and R. Scott Frey. 1991. "On the Utility of Robust and Resampling Procedures." *Rural Sociology* 56: 461–74.

Dietz, Thomas and Eugene A. Rosa. 1994. "Rethinking the Environmental Impacts of Population, Affluence and Technology." *Human Ecology Review* 1:277–300.

———. 1997. "Effects of Population and Affluence on $CO_2$ Emissions." *Proceedings of the National Academy of Sciences of the USA* 94:175–9.

Duncan, Otis Dudley. 1959. "Human Ecology and Population Studies." Pp. 678–716 in *The Study of Population*, edited by P.M. Hauser and O.D. Duncan. Chicago, IL: University of Chicago Press.

———. 1961. "From Social System to Ecosystem." *Sociological Inquiry* 31:140–9.

———. 1964. "Social Organization and the Ecosystem." Pp. 36–82 in *Handbook of Modern Sociology,* edited by R.E.L. Faris. Chicago, IL: Rand McNally.

Dunlap, Riley E. 1997. "The Evolution of Environmental Sociology: A Brief History and Assessment of the American Experience." Pp. 21–39 in *The International Handbook of Environmental Sociology*, edited by M. Reclift and G. Woodgate. Cheltenhaum, England: Elgar.

Dunlap, Riley E., Frederick H. Buttel, Peter Dickens, and August Gijswijt, eds. 2002. *Sociological Theory and the Environment: Classical Foundations, Contemporary Insights*. New York: Rowman and Littlefield.

Durkheim, Emile. [1893] 1964. *The Division of Labor in Society*. Reprint, New York: Free Press.

Ehrhardt-Martinez, Karen. 1998. "Social Determinants of Deforestation in Developing Countries: A Cross-National Study." *Social Forces* 77:567–86.

———. 1999. "Social Determinants of Deforestation in Developing Countries—Correction." *Social Forces* 78:860–1.

Ehrhardt-Martinez, Karen, Edward M. Crenshaw, and J. Craig Jenkins. 2002. "Deforestation and the Environmental Kuznets Curve: A Cross-National Investigation of Intervening Mechanisms." *Social Science Quarterly* 83:226–43.

Ehrlich, Paul and John Holdren. 1970. "The People Problem." *Saturday Review*, July 4, pp. 42–43.

———. 1971. "Impact of Population Growth." *Science* 171:1212–17.

———. 1972. "A Bulletin Dialogue on the 'Closing Circle': Critique: One-Dimensional Ecology." *Bulletin of the Atomic Scientists* 28:16–27.

Espenshade, Edward B., Jr., ed. 1993. *Goode's World Atlas*. 18th ed. New York: Rand McNally.

Ferguson, Andrew R. B. 2002. "Assumptions Underlying Eco-Footprinting." *Population and Environment* 23:303–13.

Foster, John Bellamy. 1999. "Marx's Theory of Metabolic Rift: Classical Foundation for Environmental Sociology." *American Journal of Sociology* 105:366–405.

———. 2000. *Marx's Ecology: Materialism and Nature*. New York: Monthly Review.

Frank, David John, Ann Hironaka, and Evan

Schofer. 2000. "The Nation-State and the Natural Environment over the Twentieth Century." *American Sociological Review* 65:96–116.

Freedom House. 1997. *Freedom in the World: 1996–1997*. New York: Freedom House.

Freese, Lee. 1997a. *Evolutionary Connections*. London, England: JAI Press.

———. 1997b. *Environmental Connections*. London, England: JAI Press.

Frey, R. Scott. 1994. "The International Traffic in Hazardous Wastes." *Journal of Environmental Systems* 23:165–77.

———. 1995. "The International Traffic in Pesticides." *Technological Forecasting and Social Change* 50:151–69.

———. 1998a. "The Export of Hazardous Industries to the Peripheral Zones of the World-System." *Journal of Developing Societies* 14:66–81.

———. 1998b. "The Hazardous Waste Flow in the World-System." Pp. 84–103 in *Space and Transport in the World System*, edited by P. Ciccantell and S.G. Bunker. Westport, CT: Greenwood.

Giddens, Anthony. 1990. *The Consequences of Modernity*. Stanford, CA: Stanford University Press.

———. 1991. *Modernity and Self-Identity: Self and Society in the Late Modern Age*. Stanford, CA: Stanford University Press.

———. [1999] 2000. *Runaway World*. Reprint, New York: Routledge.

Goldman, Michael. 2001. "Constructing an Environmental State: Eco-governmentality and other Transnational Prectices of a 'Green' World Bank." *Social Problems* 48:499–523.

Goldman, Michael and Rachel A. Schurman. 2000. "Closing the 'Great Divide': New Social Theory on Society and Nature." *Annual Review of Sociology* 26:563–84.

Graedel, Thomas and Braden Allenby. 1995. *Industrial Ecology*. Englewood Cliffs, NJ: Prentice Hall.

Grossman, Gene and Alan Krueger. 1995. "Economic Growth and the Environment." *Quarterly Journal of Economics* 110:353–77.

Hajer, Maarten A. 1995. *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process*. Oxford, England: Clarendon.

Harris, Marvin. 1971. *Culture, Man, and Nature*. New York: Crowell.

———. 1979. *Cultural Materialism: The Struggle for a Science of Culture*. New York: Random House.

Harrison, Paul. 1993. *The Third Revolution*. London, England: Penguin.

Harrison, Paul and Fred Pearce. 2000. *AAAS Atlas of Population and Environment*. Los Angeles, CA: University of California Press.

Hawken, Paul, Amory Lovins, and L. Hunter Lovins. 1999. *Natural Capitalism: Creating the Next Industrial Revolution*. New York: Little Brown.

Hawley, Amos. 1950. *Human Ecology: A Theory of Community Structure*. New York: Ronald Press.

———. 1986. *Human Ecology: A Theoretical Essay*. Chicago, IL: University of Chicago Press.

Jevons, William Stanley. [1865] 2001. "Of the Economy of Fuel." *Organization and Environment* 14:99–104.

Kasarda, John D. and Edward Crenshaw. 1991. "Third World Urbanization: Dimensions, Theories, and Determinants." *Annual Review of Sociology* 17:467–501.

Kick, Edward, Thomas Burns, Byron Davis, David Murray, and Dixie Murray. 1996. "Impacts of Domestic Population Dynamics and Foreign Wood Trade on Deforestation." *Journal of Developing Societies* 12:68–87.

Kuznets, Simon. 1955. "Economic Growth and Income Inequality." *American Economic Review* 45:1–28.

Marx, Karl. [1867] 1967. *Capital: A Critique of Politcal Economy*. New York: International Publishers.

Mol, Arthur P. J. 1995. *The Refinement of Production: Ecological Modernization Theory and the Chemical Industry*. Utrecht, The Netherlands: Van Arkel.

———. 2001. *Globalization and Environmental Reform*. Cambridge, MA: MIT Press.

Mol, Arthur P. J. and David A. Sonnenfeld, eds. 2000. *Ecological Modernization around the World: Perspectives and Critical Debates*. Portland, OR: Frank Cass.

Mol, Arthur P. J. and Gert Spaargaren. 2000. "Ecological Modernization Theory in Debate: A Review." *Environmental Politics* 9:17–49.

Nisbet, Robert. 1982. *Prejudices: A Philosophical Dictionary*. Cambridge, MA: Harvard University Press.

Nordström, Hakan and Scott Vaughan. 1999. *Trade and Environment*. Geneva, Switzerland: World Trade Organization.

O'Connor, James. 1988. "Capitalism, Nature, Socialism: A Theoretical Introduction." *Capitalism, Nature, Socialism* 1:11–38.

———. 1994. "Is Sustainable Capitalism Possible?" Pp. 152–75 in *Is Capitalism Sustainable? Political Economy and the Politics of Ecology*, edited by M. O'Connor. New York: Guilford.

———. 1998. *Natural Causes: Essays in Ecological Marxism*. New York: Guilford.

Organization for Economic Co-operation and Development (OECD). 1998. *Globalization* *and the Environment: Perspectives from OECD and Dynamic Non-Member Economies.* New York: OECD.

Prescott-Allen, Robert. 2001. *The Wellbeing of Nations: A Country-by-Country Index of Quality of Life and the Environment.* Washington, DC: Island.

Richerson, Peter J. and Robert Boyd. 2000. "Climate, Culture, and the Evolution of Cognition." Pp. 329–46 in *Evolution of Cognition*, edited by C. Heyes and L. Huber. Cambridge, MA: MIT Press.

Roberts, J. Timmons and Peter E. Grimes. 1997. "Carbon Intensity and Economic Development 1962–1971: A Brief Exploration of the Environmental Kuznets Curve." *World Development* 25:191–8.

———. 2002. "World-System Theory and the Environment: Toward a New Synthesis." Pp. 167–94 in *Sociological Theory and the Environment: Classical Foundations, Contemporary Insights*, edited by R. E. Dunlap, F. H. Buttel, P. Dickens, and A. Gijswijt. New York: Rowman and Littlefield.

Roberts, J. Timmons and Alexis A. Vásquez. 2002. "State Environmentalism Revisited: Structural Predictors of Nations' Propensity to Sign Environmental Treaties or Who Signs Environmental Treaties and Why? A World-System Analysis." Paper presented at the International Studies Association Conference, March 14, New Orleans, LA.

Rosa, Eugene A. and Thomas Dietz. 1998. "Climate Change and Society: Speculation, Construction, and Scientific Investigation." *International Sociology* 13:421–55.

Rosa, Eugene A., Richard York, and Thomas Dietz. 2001. "Modernization and the Environment: Modeling the Impacts of Economic Development." Paper presented at the International Sociological Association conference on "New Natures, New Cultures, New Technologies," July 6, Cambridge, England.

Rothman, Dale S. 1998. "Environmental Kuznets Curves—Real Progress or Passing the Buck?" *Ecological Economics* 25:177–94.

Salzman, James. 2000. "Environmental Protection beyond the Smokestack: Addressing the Impact of the Service Economy." *Corporate Environmental Strategy* 7:20–37.

Samuelson, Paul A. and William D. Nordhaus. 1992. *Economics.* New York: Richard D. Irwin.

Schnaiberg, Allan. 1975. "Social Syntheses of the Societal-Environmental Dialectic: The Role of Distributional Impacts." *Social Science Quarterly* 56:5–20.

———. 1980. *The Environment: From Surplus to Scarcity.* New York: Oxford University Press.

Schnaiberg, Allan and Kenneth A. Gould. 1994. *Environment and Society: The Enduring Conflict.* New York: St. Martin's.

Simon, Julian L. 1981. *The Ultimate Resource.* Princeton, NJ: Princeton University Press.

———. 1996. *The Ultimate Resource 2.* Princeton, NJ: Princeton University Press.

Snyder, David and Edward L. Kick. 1979. "Structural Position in the World System and Economic Growth, 1955–1970: A Multiple-Network Analysis of Transnational Interactions." *American Journal of Sociology* 84: 1096–1126.

Sonnenfeld, David A. 1998. From Brown to Green? Late Industrialization, Social Conflict, and Adoption of Environmental Technologies in Thailand's Pulp Industry. *Organization and Environment* 11:59–87.

Spaargaren, Gert. 1997. "The Ecological Modernization of Production and Consumption: Essays in Environmental Sociology." Ph.D. dissertation. Department of Environmental Sociology, Wageningen University, Wageningen, The Netherlands.

Spaargaren, Gert, Arthur P. J. Mol, and Frederick H. Buttel. 2000. *Environment and Global Modernity.* London, England: Sage.

Stern, David I. 1998. "Progress on the Environmental Kuznets Curve?" *Environment and Development Economics* 3:173–96.

Stern, Paul C., Oran R. Young, and Daniel Druckman, eds. 1992. *Global Environmental Change.* Washington, DC: National Academy.

Turner, B. L., II, William C. Clark, Robert W. Kates, John F. Richards, Jessica T. Mathews, and William B. Meyer. 1991. *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosperhe over the Past 300 Years.* New York: Cambridge University Press.

United Nations Population Division. 1998. *Annual Populations, 1950–2050* (1998 Revision) [MRDF]. United Nations, Department of Social and Economic Affairs, New York [producer/distributor].

van den Bergh, Jeroen C. J. M. and Harmen Verbruggen. 1999. "Spatial Sustainability, Trade and Indicators: An Evaluation of the 'Ecological Footprint.'" *Ecological Economics* 29:61–72.

Vitousek, Peter M., Harold A. Mooney, Jane Lubchenko, and Jerry A. Melilo. 1997. Human Domination of Earth's Ecosystems." *Science* 277:494–9.

Wackernagel, Mathis, Alejandro Callejas Linares, Diana Deumling, Niels B. Schulz, Maria Antonieta Vasquez Sanchez, and Ina Susana López Falfán. 2000. *Living Planet Report 2000.* Produced by the World Wide Fund for Nature International (Switzerland) together with the UNEP World Conservation Monitoring Centre (United Kingdom), the Centre for Sustainability Studies (Mexico), and Redefining Progress (United States). Retrieved August 5, 2001 (http://panda.org/livingplanet/lpr00/).

Wackernagel, Mathis, Larry Onisto, Patricia Bello, Alejandro Callejas Linares, Ina Susana López Falfán, Jesus Méndez García, Ana Isabel Suárez Guerrero, and Ma. Guadalupe Suárez Guerrero. 1999. "National Natural Capital Accounting with the Ecological Footprint Concept." *Ecological Economics* 29:375–90.

Wackernagel, Mathis and William Rees. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth.* Gabriola Island, British Columbia, Canada: New Society.

Wallerstein, Immanuel. 1974. *The Modern World-System I: Capitalist Agriculture and the Origins of the European World Economy in the Sixteenth Century.* New York: Academic.

World Resources Institute (WRI), United Nations Environment Programme, United Nations Development Programme, and World Bank. 1996. *World Resources 1996–1997: A Guide to the Global Environment: The Urban Environment.* New York: Oxford University Press.

———. 1998. *World Resources 1998–1999: A Guide to the Global Environment: Environmental Change and Human Health.* New York: Oxford University Press.

———. 2000. *World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life.* New York: Oxford University Press.

York, Richard, Eugene A. Rosa, and Thomas Dietz. 2001. "The Population and Affluence Elasticity of Environmental Impacts." Paper presented at the annual meeting of the Pacific Sociological Association, March 29, San Francisco, CA.

———. 2002. "Bridging Environmental Science with Environmental Policy: Plasticity of Population, Affluence, and Technology." *Social Science Quarterly* 83:18–34.