Are the Economy and the Environment Decoupling? A Comparative International Study, 1960–2005[1]

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Ecological modernization theory posits that even though economic development harms the environment, the magnitude of the harmful link decreases over the course of development. In contrast, the treadmill of production theory argues that the strong relationship between environmental harms and economic development will remain constant or possibly increase through time. To evaluate these competing propositions, interactions between economic development and time are used in cross-national panel analyses of three measures of carbon dioxide emissions. The results vary across the three outcomes as well as between developed and less developed countries, providing mixed support for both theoretical perspectives. The authors conclude by discussing how both theories could benefit from engaging contemporary research concerning changes within the transnational organization of production and the structure of international trade and how these global shifts influence environment/economic development relationships.

INTRODUCTION

Comparative sociology is full of theoretical debates and empirical analyses that consider structural relationships that might vary in magnitude

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through time. For example, within the sociology of development literature, Firebaugh and Beck (1994) contend that economic development serves as the basis to improve the overall well-being of people within less developed countries. However, other scholars emphasize the limitations of this "growth consensus" orientation and empirically demonstrate that while economic development contributes to the well-being of the populations of developing countries, through time the magnitude of development's positive effect on various well-being outcomes has decreased to a nontrivial extent (Brady, Kaya, and Beckfield 2007; see also Sen 1999). In other words, a relative decoupling of economic development and human well-being has taken place within many less developed countries. Other strands of macrosociological research show that, during the recent upswing in the globalization of trade (Chase-Dunn, Kawano, and Brewer 2000), such exchanges between developed and less developed countries have become increasingly ecologically unequal—a form of intensification (e.g., Jorgenson and Clark 2009; see also Bunker 1984; Rice 2007). This mode of intensification runs counter to certain assumptions in sociology and economics about the relative and absolute benefits of trade for all participating nations (e.g., Sanderson 1999; Gilpin 2001).

Similarly to other areas of the discipline, a central theme in environmental sociology concerns the possibility for a particular type of either decoupling or intensification to take place. Here the focus is on the environment/economic development relationship and the extent to which the magnitude of the environmental impacts of development might change through time in macrocomparative contexts. While foundational theories in contemporary environmental sociology—particularly the ecological modernization theory (e.g., Mol 2001) and the treadmill of production theory (e.g., Gould, Pellow, and Schnaiberg 2008)—are at loggerheads over this relationship and its temporal stability, their opposing propositions are in great need of rigorous and balanced empirical assessment. Economic development generally requires material inputs and generates forms of waste. Even with their recent modest decoupling in less developed countries, development continues to enhance the well-being of human societies in a variety of ways. Thus, the environment/economic development relationship speaks to a variety of broader sociological themes, well beyond the core of environmental sociology. And in a related vein,

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the intersections of environment, economic development, and human well-being are at the heart of sustainable development discourse (Harper 2004), and sociology, perhaps more than any other social science discipline, is well equipped to consider such relationships (e.g., Dunlap and Catton 1979; Giddens 2009). Research along these lines can complement and contribute to the policy literature that addresses the potential decoupling of environmental harms and economic development within nations or larger macroregions (OECD 2002; European Commission 2005).[2]

In the current study we evaluate the competing arguments of the ecological modernization theory and the treadmill of production theory concerning the environmental impacts of economic development and the extent to which this relationship has decoupled or intensified. To do so, we conduct cross-national panel analyses from 1960 to 2005 to assess the effects of economic development on three measures of anthropogenic carbon dioxide emissions: total emissions, per capita emissions, and emissions per unit of production. We employ appropriate interactions between economic development and time to analyze how and the extent to which economic development's effect changes in magnitude through time. For theoretical reasons, we also assess the temporal stability of the relationships for developed and less developed countries separately, as ecological modernization suggests that decoupling occurs first in developed countries, whereas the treadmill of production generally questions the prospects of decoupling in any nation, regardless of its location across the global North/South divide.[3]

There are three reasons for analyzing carbon dioxide emissions. First, there is scientific consensus that anthropogenic carbon dioxide emissions are a primary contributor to climate change (e.g., U.S. National Research Council 2010). Second, countless economic-related activities require the burning of fossil fuels, which results in carbon dioxide emissions. Third, there are much more cross-national panel data available for anthropogenic carbon dioxide emissions than any other type of environmental harm, and

[2] The focus of existing policy research is often on constructing new and/or identifying existing indicators to measure such shifting relationships where environmental harms and the consumption of natural resources are reduced relative to economic growth. We thank a reviewer for suggesting that we reference these bodies of policy literature. Further, within policy and social science research there is an important distinction between *relative* and *absolute* decoupling. The former refers to a situation in which the increase in the environmental harm measure is less than the growth rate of the economic variable. The latter indicates that the environmental measure is stable or actually decreases in relation to an increase in the economic variable (OECD 2002).

[3] Comparisons between developed countries and less developed countries of statistical associations are common in numerous areas of contemporary sociological inquiry (e.g., Alderson and Beckfield 2004; Longhofer and Schofer 2010).

these data have become increasingly reliable and valid for comparisons between and within nations through time (World Bank 2007; WRI 2007).[4]

We begin with a discussion of the ecological modernization theory and the treadmill of production theory in which we highlight their competing propositions concerning the economic development/environment relationship and why we might expect to see differences in such relationships in developed countries relative to within less developed countries. Next, we briefly describe the three measures of carbon dioxide emissions employed as dependent variables in the study and highlight their unique implications for policy. We continue by describing the panel data sets, the model estimation technique, and all the variables employed in the panel analyses. Following the presentation of the findings for the panel analyses, we conclude by discussing the key results of the study and their theoretical significance. We reflect on the insights and shortcomings of the tested theories and call attention to additional sociologically relevant factors that might help to partially explain our diverse findings. In this reflection we suggest that both theories will benefit from further consideration of shifts in the transnational organization of production and the structure of international trade and how these changes are influencing the relationships between the environment and economic development.

DIVERGENT PERSPECTIVES ON THE ECONOMY AND THE ENVIRONMENT

Ecological Modernization

Ecological modernization is one of the leading theories in environmental sociology and focuses on “how various institutions and social actors attempt to integrate environmental concerns into their everyday functioning, development, and relationships with others, including their relation with the natural world” (Mol, Spaargaren, and Sonnenfeld 2009, p. 4). It emphasizes that the market and industrialism play an important role in environmental reform. Economic growth, technological development, and environmental consciousness are seen as key factors in transforming production. These transformative processes help dematerialize the economy as relatively fewer natural resources are required to sustain society.

Ecological modernization theorists explain that during the early stages

[4] Related to both the first reason and our attempts to compare the emissions/development relationships for developed and less developed countries, the human consequences of climate change in the contemporary period are already disproportionately felt by the populations of many nations within the global South, particularly those in coastal areas and those hampered by food security challenges and weak infrastructures (e.g., Kolbert 2006; Roberts and Parks 2007; Stern 2007).

of modernization, "economic rationality" is used as the basis to evaluate social relationships and development. Here economic growth is the measuring stick of progress, whereas social and environmental ills are seen as minor consequences. As a result, the early stages of economic development generally involve significant environmental degradation. In contrast, late modernity holds the potential for reflexivity and critical assessments, in part spurred on by social movements, the scientific community, government officials, and business leaders. An "ecological rationality" emerges and percolates throughout social structures, as environmental concerns integrate with self-interests, which influence society/nature relations and considerations (Mol 1995, 2001). In a similar vein, Ronald Inglehart's "postmaterialist values" thesis posits that in the past, societies and individuals had to remain focused on survival or material concerns; however, with the rise of the welfare state and the economic growth of advanced industrial and postindustrial societies, survival needs no longer have to be a top priority, giving rise to postmaterialist values including freedom of choice and the improvement of environmental conditions (e.g., Inglehart 1990, 1997; Inglehart and Baker 2000).[5] For instance, individuals may choose to support environmental legislation, such as the designation of wilderness areas, or may decide to buy "green" products.

Rather than calling for changes in social order and structures of organization, "the environmental crisis can and should be overcome by a further modernization of the existing institutions of modern society" (Spaargaren 1997, p. 25). Here "market dynamics and economic actors have a distinct role to play on the stage of environmental reform" as "global capitalist developments" help "trigger or mediate environmental innovations and reform" (Mol 2002, p. 102). Social movements as well as other civil society configurations that embody notions of ecological rationality exert pressure on economic actors to make environmental improvements and to pursue green technological innovations. "Environmental improvement can go together with economic development via a process of delinking economic growth from natural resource inputs and outputs of emissions and wastes" (Mol 1997, p. 141).[6] In other words, "environ-

[5] Recent cross-national and multilevel studies of environmental attitudes, which attempt to test Inglehart's thesis, yield mixed results (e.g., Dunlap and York 2008; Givens and Jorgenson 2011).

[6] Ecological modernization theory is similar to a branch of environmental economics that recognizes that economic development generates environmental harms but argues that further growth can largely correct these problems (e.g., Grossman and Krueger 1995; Dinda 2004). According to the latter approach, the environment is seen as a luxury good, subject to public demand through the workings of an advanced market. During the early stages of development, environmental impacts escalate, but as afflu-

mental reform can even result in an absolute decline in the use of natural resources and discharge of emissions, regardless of economic growth in financial or material terms (product output)" (Mol 2002, p. 93).[7]

The general shift toward ecological modernization is partially facilitated by technological innovations. Huber (2009, pp. 334–35) explains that the emerging order is not about using "old technologies differently." Instead, "new and different technologies" are developed, including fuel-less energy (e.g., "clean-burn hydrogen" and/or photovoltaics) and nanotechnology. Such "technological environmental innovations" are often geared "to reduce the quantities of resources and sinks used"—whether measured by intensity, per unit, or in "absolute volumes" (p. 335). In this context, a "green economy" emerges as economic development enhances the ecological integrity and energy efficiency of social production, which reduces levels of resultant carbon dioxide emissions.

As economic and ecological concerns become more integrated, the flexibility of the economic system to produce and offer green choices increases (Spaargaren 2009; Spaargaren and Cohen 2009). New markets arise, which allow for further investment opportunities to expand the avenues for cleaner production and sustainable consumption. These social, economic, and technological transformations are likely to first take place within developed countries, but through time they will possibly diffuse to and thus occur in less developed countries. In the world economy, ecological modernization "has a universalizing effect on the way in which countries experience and design environmental reform" (Mol 2002, p. 112).

Economic growth and environmental protection are seen as generally compatible (Hajer 1995). While it is recognized that there is variation between countries as well as broader variations between the global North and the global South, as far as success addressing ecological concerns, technological transfers between nations and economic integration facilitate the prospects of "significant environmental improvement" throughout the world (Sonnenfeld and Rock 2009, p. 366). Recently, ecological modernization scholars have focused on the socioeconomic transformations in

ence within these societies rises, the value the public places on the environment will increase. It is argued that if the market is allowed to operate without dramatic interference, continuing development will lead to a leveling and eventual decline in the use of natural resources and emission of pollutants. The proposed trend, known as the environmental Kuznets curve (EKC), is depicted as an inverted U-shaped distribution representing the relationship between environmental impacts and economic development (see York, Rosa, and Dietz [2003], Jorgenson and Birkholz [2010], Jorgenson and Clark [2011], and Dietz, Rosa, and York [2012] for extended discussions comparing ecological modernization theory and the EKC hypothesis in environmental economics).

[7] In this study, we assess whether or not there is evidence of a relative decoupling over time, which we consider a more conservative assessment than to evaluate arguments concerning the possibility of absolute decoupling.

the "emerging economies" in Asia and elsewhere, noting that "environmental reforms *are* being developed and instituted" as an ecological rationality becomes more universal (p. 361).

Ecological modernization theory contributes greatly to our understanding of how modern institutions respond to environmental problems. It highlights how various technological advances and innovations within modern industry could lead to the dematerialization of production and society, reducing energy and material consumption. Proponents of ecological modernization suggest that economic development in an era of ecological consciousness will reduce the environmental burdens of society. As a result, through time, a relative decoupling between economic development and environmental degradation is possible and likely to occur first in developed countries. More specifically, ecological modernization theory would suggest that while economic development will continue to affect total, per capita, and per unit of production carbon dioxide emissions, the magnitude of economic development's effect will likely decrease through time. Further, such decouplings are more likely to occur first in developed countries than in less developed countries (e.g., Mol 1995; Spaargaren 2009; see also Dietz, Rosa, and York 2010, p. 106).

Treadmill of Production

In contrast to the ecological modernization perspective, the treadmill of production theory posits that environmental degradation and pollution are an inherent part of economic development (Schnaiberg 1980; Schnaiberg and Gould 1994). Given that the capitalist economy is predicated on the constant pursuit of profit and expansion, its operations have "direct implications for natural resource extraction," the generation of pollution, and the overall state of environmental conditions (Gould, Pellow, and Schnaiberg 2004, p. 297). Hence, the economy generates ecological problems, as it must continually withdraw resources from the environment to produce products and power machinery, and such activities also generate waste. The state, while often caught in contradictory positions, is seen as an important social institution that supports economic expansion through negotiating trade agreements, bailing out industry and banking, promoting military spending, and protecting private property.

More specifically, the treadmill of production perspective focuses on how socioeconomic relationships influence the interchange of "environmental withdrawals and additions" between nature and society (Schnaiberg 1980, p. 230). Schnaiberg argues that competition and the concentration of capital drive the treadmill of production. Profits are invested in production as a means of enlarging and intensifying the scale of operations. Technological innovation is an important component of the treadmill. It often simplifies the labor process, allowing companies to automate production and reduce costs. At the same time, new technologies may improve the economic efficiency of production, potentially decreasing the amount of energy consumed *per unit of production*. The amount of raw material used in the production of particular commodities might decrease as well. However, technological innovation could allow for more units to be made within a specific amount of time, and growth in the scale and intensity of production might increase the total energy consumed, the amount of materials used, and the amount of waste generated and emitted. In a related vein, recent strands of research suggest that enhancing energy efficiency does not necessarily decrease energy consumption. As suggested by the "Jevons paradox," greater efficiency in resource use may actually increase the overall consumption of that particular resource.[8] Thus, any gains made in energy efficiency are outstripped by the growth in resource use via the expansion of commodity production (Jevons 1865; Clark and Foster 2001; York 2006; Polimeni et al. 2008; Jorgenson 2009). In this context, the treadmill of production theory suggests that it is possible to increase energy and resource use efficiency within the economy. But whether efficiency increases actually lead to a decoupling of economic development and the environment is questioned, and it remains an issue in need of empirical consideration (Schnaiberg 1980).

More generally, the treadmill of production perspective suggests that the strong relationship between environmental harms and economic development has remained fairly constant or possibly increased through time. The drive to expand production necessitates a constant withdrawal of natural resources from ecosystems at rates that generally exceed the regenerative capacity of these systems (see Foster 2002; Clark and York 2005*b*; Foster, Clark, and York 2010). Additionally, modern industries pursue economic efficiencies to enhance the production process and to increase profit margins. Energy-intensive materials, such as plastics and chemicals, are incorporated into manufacturing, generating a broad range of waste (Schnaiberg and Gould 1994; Pellow 2007). Producers attempt to externalize environmental costs, such as industrial water pollution and carbon dioxide emissions, as much as possible as this has the potential to enhance profits.

Like the ecological modernization theory, the treadmill of production

[8] This paradox is named after the British economist William Stanley Jevons, who observed in the 19th century that as the efficiency of coal use by industry improved, total coal consumption increased. He noted that improvements in efficiency made coal more cost effective per unit of production, making coal-dependent production more attractive (Jevons [1865] 1906).

theory stresses that human civilization is dependent on the biophysical world, but the latter is skeptical of the notion that the relationship between economic development and environmental degradation should decrease in magnitude or strength over time, regardless of a country's level of development. Rather, it argues that the constant drive to expand capital increases the volume of natural resources and energy that are extracted and used to sustain the productive operations on a larger and more intensive scale (Gould et al. 2004). This treadmill dynamic is further set in motion as developing nations pursue a similar path of economic development. As a result, the treadmill of production theory would posit that the effect of economic development on the carbon dioxide emissions of nations, whether they are measured by scale, intensity, or ecoefficiency, should remain stable or perhaps increase in magnitude through time, regardless of whether countries are developed or less developed (Gould et al. 2008). As articulated by Mol (2001, p. 205), this theoretical argument runs counter to the propositions of the ecological modernization theory: "we are moving beyond the era of a global treadmill of production that only further degrades the environment." Rather, the ecological modernization theory points to the potential for the environmental impacts of development to decrease in magnitude and for such changes to occur first in the developed countries of the global North (Mol 1997; Huber 2009).

In the cross-national panel analyses below, we assess the above propositions of the treadmill of production perspective as well as the opposing arguments of the ecological modernization theory concerning the possibility of a decoupling between the environment and economic development.[9] Prior to presenting the panel analyses, we provide a brief concep-

[9] Notable bodies of scholarship in both the ecological modernization and treadmill of production traditions consist of in-depth case studies (e.g., Mol 1995; Gould, Schnaiberg, and Weinberg 1996; Sonnenfeld 1998; Andersen 2002), and prior quantitative cross-national analyses also attempt to test one or both theories simultaneously (e.g., York et al. 2003; Fisher and Freudenburg 2004; Jorgenson 2006). Like all forms of sociological inquiry, these works have limitations. The case studies in either orientation tend to be on particular firms or communities, both of which are limited in their generalizability, and some scholars consider these smaller units of analysis a relative weakness as well (e.g., York and Rosa 2003). However, one of the biggest strengths of this previous work is the attention paid to the underlying mechanisms that lead to the environmental outcomes under investigation. Most of the prior cross-national analyses are limited by their cross-sectional design, thereby disallowing rigorous and balanced testing of the key propositions of the two theories that focus on the temporality of environment/economy relationships; the latter are highlighted in our theoretical discussion and literature review. While the cross-sectional design is a key weakness of these prior quantitative works, their larger unit of analysis and comparative nature are strengths relative to the case studies. Our narrative treatment and empirical assessment of both theories overcome the above limitations of these bodies of research. Further, the underlying mechanisms illuminated by prior case studies are integrated into our discussion of both perspectives and contribute to the ways in which

tual discussion of the three carbon dioxide emissions measures employed as dependent variables in our study.[10]

THREE MEASURES OF ANTHROPOGENIC CARBON DIOXIDE EMISSIONS

Three measures of anthropogenic carbon dioxide emissions are dominant in scientific inquiries and policy discourse on climate change: total emissions, per capita emissions, and emissions per unit of production (i.e., per unit of gross domestic product [GDP]).[11] While not entirely independent of one another, each type of measure captures unique characteristics of anthropogenic emissions of relevance to both the ecological modernization theory and the treadmill of production theory (i.e., scale, intensity, and ecoefficiency). In the interest of rigorous, balanced, and thorough assessments of both orientations, we treat all three as dependent variables in the panel analyses.

The first measure, total emissions, focuses on scale. It is the most important measure when considering climate change, given that it is the overall accumulation of emissions in the atmosphere that contributes to global warming (e.g., Rosa, York, and Dietz 2004; IPCC 2007*b*; Hansen et al. 2008; U.S. National Research Council 2010). Research in various earth and social science disciplines suggests that the human and environmental consequences of climate change in less developed countries are disproportionately influenced by the cumulative total anthropogenic emissions resulting from activities in developed countries (IPCC 2007*b*; Roberts and Parks 2007; Stern 2007), which further underscores the impor-

we characterize their convergent positions concerning possible decoupling or intensification of the emissions/development relationships in macrocomparative contexts.

[10] It is important to recognize that various global-institutional conditions and processes, such as the collective identification of the human causes and consequences of emissions, the attendant solutions and regulatory mechanisms, and the emergence of world environmental regime agents (e.g., the growth and spread of environmental international nongovernmental organizations [EINGOs]), all likely—to some extent—influence levels of carbon dioxide emissions around the world. Indeed, strands of research in the world society tradition within sociology provide evidence of their relevance (e.g., Shandra et al. 2004; Schofer and Hironaka 2005). While considering such factors with appropriate depth—both theoretically and empirically—is well beyond the scope of our study, we discuss in n. 16 below a series of unreported sensitivity analyses in which we control for numerous global-institutional characteristics that yield results consistent with the reported findings.

[11] In climate discussions, total emissions can also refer to total anthropogenic carbon dioxide emissions for the entire world, which is the key consideration as far as climate change is concerned. At the same time, it is common practice within both the earth and social sciences to analyze total carbon dioxide emissions at the nation-state level (IPCC 2007*a*, 2007*b*; Roberts and Parks 2007; Stern 2007).

tance in assessing separately the relationships between total emissions and development in developed countries and less developed countries.

The second measure, per capita emissions, assesses international inequalities in carbon emissions and is a common measure of emissions intensity in prior sociological research (e.g., Shandra et al. 2004; Jorgenson, Dick, and Mahutga 2007; Rosa et al. 2010).[12] The atmosphere is viewed as a global commons, where carbon pollution accumulates over time. From this perspective, every person in the world has equal rights to the atmosphere, and the amount of allowable pollution should be determined on a per capita basis (Argawal and Narain 1991). The per capita measure reveals how particular nations—when adjusted for differences in population size—might be responsible for a disproportionate amount of the carbon dioxide emissions in the global commons.

The third measure, emissions per unit of production, is widely used to quantify relative levels of ecoefficiency (e.g., Roberts, Grimes, and Manale 2003; Polimeni et al. 2008; York, Rosa, and Dietz 2009). The ecoefficiency of economies is improved through technological innovations that increase the efficiency of fossil-fuel use and the incorporation of low-carbon energy sources. Politicians and business-funded policy groups as well as sustainable development advocates often prefer this measure as it assesses emissions relative to overall economic production, proposing that if the economy becomes more ecoefficient (i.e., fewer carbon emissions per dollar of GDP), growth of carbon dioxide emissions will slow and possibly begin to reverse while economies continue to expand (OECD 2002; White House 2002; European Commission 2005).

THE PANEL ANALYSES

The Data Sets

We analyze a balanced data set that consists of 10 observations per country at five-year increments from 1960 to 2005. With an overall number of 860 observations, the data set consists of 86 developed and less developed countries. We include all nations with populations of at least 1 million for the entire period of investigation where data are available for all outcomes and predictors at each of the 10 time points. Data availability at the time of this study precludes us from including time points before 1960 or after 2005. Table 1 lists the countries (22 developed and 64 less developed) included in the analyses. As discussed below, we also split the

[12] Here, intensity refers to carbon emissions in relation to population rather than an economic conceptualization of intensity, such as emissions in relation to the size of an economy.

TABLE 1
COUNTRIES INCLUDED IN THE ANALYSES

Developed Countries	Less Developed Countries		
Australia	Algeria	Georgia	Pakistan
Austria	Argentina	Ghana	Panama
Belgium	Bangladesh	Guatemala	Papua New Guinea
Canada	Benin	Haiti	Paraguay
Denmark	Bolivia	Honduras	Peru
Finland	Brazil	Hungary	Philippines
France	Burkina Faso	India	Rwanda
Greece	Burundi	Indonesia	Senegal
Ireland	Cameroon	Iran	Sierra Leone
Israel	Central African Rep.	Kenya	South Africa
Italy	Chad	Latvia	Sri Lanka
Japan	Chile	Liberia	Sudan
Korea, Rep.	China	Madagascar	Syrian Arab Rep.
Netherlands	Colombia	Malawi	Thailand
New Zealand	Congo, Dem. Rep.	Malaysia	Togo
Norway	Congo, Rep.	Mauritania	Tunisia
Portugal	Costa Rica	Mexico	Uruguay
Spain	Cote d'Ivoire	Morocco	Venezuela
Sweden	Dominican Rep.	Nepal	Zambia
Switzerland	Ecuador	Nicaragua	Zimbabwe
United Kingdom	Egypt	Niger	
United States	El Salvador	Nigeria	

NOTE.—Developed countries are those in the upper quartile of the World Bank's (2007) income classification of nations; less developed countries are those that fall below the upper quartile.

overall sample into two data sets, one for the 22 developed countries (220 total observations) and one for the 64 less developed countries (640 total observations). These two data sets are employed in the series of final estimated models for each of the three outcomes.

While our study has great temporal depth relative to most cross-national research on society/nature relationships and the overall analyzed sample includes a diverse set of countries from most macroregions, an unintended consequence and limitation of this approach is the exclusion of many nations where data are available only for more recent yearly observations, most notably countries formerly a part of the Soviet Union.[13] We recognize this important limitation. However, considering the focus of the current study and our approach to assessing the converse propositions of the two dominant theoretical orientations, balanced panel data sets with temporal

[13] As shown by York (2008) in his study of former Soviet republics from 1992 to 2000, many of these nations experienced declines in both levels of economic development and carbon dioxide emissions during this short period, which he believes runs counter to the claims of ecological modernization theory (see also Jorgenson 2011).

depth are important and quite appropriate. If data availability was not an issue, we would prefer to include more nations, especially former Soviet republics.

Model Estimation Technique

We use a time-series cross-sectional Prais-Winsten (PW) regression model with panel-corrected standard errors (PCSE), allowing for disturbances that are heteroskedastic and contemporaneously correlated across panels (Cameron and Trivedi 2009, pp. 267–68). We employ PCSE because the feasible generalized least-squares estimator that is often used to analyze panel data produces standard errors that can lead to extreme overconfidence with panel data sets that do not have many more time periods than panels (Beck and Katz 1995). We correct for AR(1) disturbances (i.e., first-order autocorrelation) within panels, and since we have no theoretical basis for assuming that the process is panel specific, we treat the AR(1) process as common to all panels (Beck and Katz 1995, p. 638). We control for both period-specific and unit-specific disturbances. Our general model is as follows:

$$y_{it} = \beta x_{it} + u_i + w_t + e_{it}.$$

Subscript i represents each unit of analysis (i.e., country), subscript t represents the time period, and y_{it} is the dependent variable for each country at each time period. The term βx_{it} represents the vector of coefficients for predictor variables that vary over time, u_i is the unit-specific (i.e., country-specific) disturbance term, w_t is the period-specific disturbance term that is constant across all countries, and e_{it} is the disturbance term unique to each country at each point in time. We calculate and employ dummy variables to control for u_i and w_t. The former controls for potential unobserved heterogeneity that is temporally invariant within countries (unit-specific intercepts), and the latter controls for potential unobserved heterogeneity that is cross-sectionally invariant within periods (period-specific intercepts). The unit-specific intercepts approach is analogous to the dummy variable fixed-effects model (Allison 2009, pp. 14–16), often referred to as one-way fixed effects (Baum 2006). Similarly, the inclusion of the period-specific intercepts is equivalent to modeling temporal fixed effects, and including both period-specific and unit-specific intercepts is analogous to estimating a two-way fixed-effects model (Baum 2006, pp. 224–25). Including period-specific intercepts also lessens the likelihood of biased model estimates resulting from outcomes and predictors with relatively similar time trends (Wooldridge 2005, p. 366). Overall, our modeling approach is robust against potentially omitted control variables and more closely approximates experimental conditions than other panel model approaches (Hsiao 2003). The panel analyses are conducted with the xtpcse suite of commands in Stata (ver. 9) software.[14]

Dependent Variables

We analyze three measures of anthropogenic carbon dioxide emissions: total emissions, per capita emissions, and emissions per unit of GDP. As highlighted earlier in this article, the first measure has the most significance for sustainability issues in general and climate change in particular, the second is most relevant from an international inequality perspective, and the third is the most common measure of ecoefficiency in scientific and policy settings.

We obtain the carbon dioxide emissions data from the World Resources Institute (WRI 2007). These data represent the mass of carbon dioxide produced during the combustion of solid, liquid, and gaseous fuels, as well as from gas flaring and the manufacture of cement. They do not include emissions from land use change or emissions from bunker fuels used in international transportation. More specifically, the emissions data come from the WRI's Climate Analysis Indicators Tool (CAIT), which is an information and analysis tool on global climate change.[15] CAIT provides a comprehensive and comparable database of greenhouse gas emissions data (including all major sources and sinks) and other climate-relevant indicators. In order to provide the most complete and accurate data set, CAIT compiles data from three sources: the Carbon Dioxide Information Analysis Center, the International Energy Agency, and the Energy Information Administration.

The total emissions data are measured in metric tons. Carbon dioxide emissions per capita represent the mass of carbon dioxide emitted per person for a country in metric tons as a result of the same production and flaring processes as for the measures of total emissions. WRI calculates per capita emissions from total emissions divided by population estimates from the United Nations Population Division. Emissions per unit of GDP are calculated by dividing the total emissions by the total GDP of nations measured in constant 2000 U.S. dollars. The total GDP data are obtained from the World Bank (2007). Specifically, this dependent variable measures the metric tons of emissions per dollar of GDP. Given their extreme positive skews, all three dependent variables are logged.

[14] Elsewhere, as a sensitivity check, all models were estimated with the xtregar command in Stata, which amounts to estimating fixed-effects models with an AR(1) disturbance. The results are substantively consistent with the reported findings.

[15] For additional information on CAIT and the methodology used in calculating the carbon dioxide estimates, go to http://cait.wri.org/.

Key Independent Variables

Consistent with the majority of prior cross-national research, we include GDP per capita as a measure of a nation's level of economic development.[16] These data, which are logged to minimize skewness, are measured in 2000 constant U.S. dollars and obtained from the World Bank (2007).[17] Appendix table A1 presents the mean values of GDP per capita and all three carbon dioxide emissions measures for 1960 and 2005 as well as their mean growth rates for the appropriate five-year increments (i.e., 1960–65, … , 2000–2005). The growth rates and mean values are provided for the entire sample as well as separately for the developed countries and less developed countries included in the panel analyses.

To compare the linear effect of GDP per capita for developed countries and less developed countries, we calculate and employ an interaction between GDP per capita and a dummy variable (Hamilton 1992) for the less developed countries included in the data set (see table 1). Developed countries are those in the upper quartile of the World Bank's income

[16] To maintain the relatively large sample size and balanced character of the panel data set, we include only time-variant predictors with adequate available data that are consistently shown in prior research to affect anthropogenic carbon dioxide emissions. However, in sensitivity analyses available on request, we also include measures of manufacturing as a percentage of GDP, services as a percentage of GDP, level of democratization and state strength, environmental treaty ratification indices, two different measures of EINGO presence, and population age structure. The first five of these measures as well as population age structure were obtained from the World Bank (2007). The treaty ratification indices were gathered from Dietz and Kalof (1992) and Roberts and Parks (2007). The two measures of EINGO presence were generously provided by Jackie Smith and Dawn Wiest (see Smith and Wiest 2005) and David John Frank and Evan Schofer (unpublished data set; see also Frank, Hironaka, and Schofer 2000). The former involve a broader definition of EINGOs but are limited to observations from 1980 to 1995, whereas the latter involve a more restrictive definition of EINGOs but consist of observations from 1965 to 2005. While the inclusion of most of these predictors reduces the overall sample sizes and leads to unbalanced panel data sets, the results with all combinations of the additional measures are consistent with the reported findings.

[17] Following the suggestion of a reviewer, in sensitivity analyses available on request, we employ the most recently available GDP per capita data adjusted for purchasing power parity (PPP) as our key measures of economic development in models of all three dependent variables. These data, which we obtained from the World Bank's online database (http://www.worldbank.org), are presented in constant 2005 international dollars. They are also available for only the 1980–2005 period and are not available for Haiti, Georgia, and Zimbabwe. Thus, the sensitivity analyses are reduced to the 1980–2005 period and exclude these three nations, with an end result of six observations for 83 nations and an overall sample size of 498 observations. The results of the sensitivity analyses with the PPP measures are substantively identical to model estimates for the same nations and time points with the GDP per capita measures that are in constant 2000 U.S. dollars. We also note that the two GDP per capita measures for the 83 nations from 1980 to 2005 (point estimates in five-year increments, 498 total observations) are correlated at .988.

classification of nations for the year 2007, and less developed countries are those that fall below the upper quartile. The developed countries are the reference category in the model of each outcome that includes this interaction. As a time-invariant measure, the dummy variable for the less developed countries is excluded from the estimated model since it is perfectly correlated with and thus accounted for by the unit-specific intercepts that operate as fixed effects (Allison 2009, p. 19).[18]

We also calculate and use interactions between GDP per capita (logged) and each time point, where 1960 is the reference year. For theoretical reasons highlighted above, these measures are employed in model estimates for the overall sample as well as the two data sets restricted to only the developed countries and only the less developed countries. Such interactions allow us to assess the extent to which the effect of development on the three outcomes increases or decreases in magnitude through time. For the estimated models that include the interactions between development and time, the coefficient for GDP per capita is the unit change in the dependent variable in 1960 for each unit increase in GDP per capita for the same year. The overall effect of GDP per capita for the other time points (i.e., 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005) equals the sum of the coefficient for GDP per capita (i.e., its effect in 1960) and the appropriate interaction term if the latter is statistically significant. A nonsignificant coefficient for the latter suggests that there is no difference in the effect of GDP per capita in 1960 and the later time point.

Interactions between time and quantitative measures are relatively common in cross-national panel studies within comparative macrosociology that test various theoretically derived propositions concerning the temporal stability of relationships between predictors and outcomes (e.g., Beckfield 2003; Schofer and Meyer 2005; Brady et al. 2007; Jorgenson and Kuykendall 2008; Zhou 2010). The employment of such interactions and model estimation techniques in macrosociological inquiry—especially in analyses like ours that also employ panel model estimation techniques that account for heterogeneity bias (two-way fixed effects) and autocorrelation—speaks to their identified utility in balancing methodological rigor with relatively clear and straightforward interpretations (Bollen and Brand 2010). More broadly, the coupling of rigor and accessible inter-

[18] If one attempts to include the time-invariant dummy variable under such circumstances, Stata drops it from the estimated model.

pretations is ideal for theory testing in the social sciences (Firebaugh 2008).[19]

Additional Independent Variables

We control for total population measured in thousands (logged to minimize skewness) in all analyses of total carbon dioxide emissions (World Bank 2007). The measures of total population are based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. Refugees not permanently settled in the country of asylum are generally considered to be part of the population of their country of origin. Sociological research in the structural human ecology tradition consistently shows that population is a key driver of scale-level environmental outcomes (e.g., York et al. 2003; Rosa et al. 2004; Dietz, Rosa, and York 2007; York 2007) and that the association between total carbon dioxide emissions and population size is relatively large in magnitude and statistically time invariant for both developed and less developed countries (Jorgenson and Clark 2010).

We include measures of urban population, which quantifies the percentage of a country's population residing in urban areas. These data are gathered from the World Bank (2007). Generally speaking, urban political-economy approaches would posit positive associations between all three outcomes and levels of urbanization (e.g., Molotch 1976; Dickens 2004; Clark and York 2005*a*), and prior research yields such results (e.g., Roberts and Parks 2007; Lankao, Nychka, and Tribbia 2008; York 2008; Jorgenson, Rice, and Clark 2010).

We include trade as a percentage of GDP, which controls for the extent to which a country is integrated in the world economy. These data are also obtained from the World Bank (2007). Recent analyses show a positive association between carbon dioxide emissions and levels of international trade (e.g., Schofer and Hironaka 2005; Roberts and Parks 2007). A common explanation for these findings is that in order to be relatively competitive in the world economy, trade and other forms of economic globalization create added pressures for countries (especially less devel-

[19] Other techniques, such as moving local regression models, are capable of analyzing various forms of nonlinear and time-variant statistical associations (e.g., Fedorov, Hackl, and Muller 1993). However, we consider them less appropriate than our employed techniques for assessing the temporal stability of associations between covariates and outcomes. Our approach accounts for omitted variable bias and autocorrelation and yields estimates that can easily be interpreted and used for evaluating the competing propositions of the ecological modernization and treadmill of production theories. We thank a reviewer for suggesting that we consider these issues.

oped countries) to lower environmental standards for export-oriented production (e.g., McMichael 2008; Dietz et al. 2010).

Appendix tables A2, A3, A4, and A5 provide descriptive statistics and bivariate correlations for all dependent variables and independent variables included in the reported panel analyses.

The Estimated Models

We estimate three models for each of the three carbon dioxide emissions variables (total emissions, per capita emissions, and emissions per unit of GDP). The estimated models are identical across the three outcomes except for the inclusion of total population as an independent variable in all models of total emissions. In the estimated models, countries are indexed by i, years are indexed by t, u_i specifies a unique intercept for each country, and e_{it} is the disturbance term unique to each country at each point in time. The first model, labeled model A in tables 2–4, is as follows:

$$\begin{aligned}\text{Total Carbon Dioxide Emissions}_{it} = {}& \\ &\beta_1\text{GDP per capita}_{it} + \beta_2\text{Urban Population}_{it} \\ &+ \beta_3\text{Trade}_{it} + \beta_4\text{Population}_{it} + \beta_5\text{year 1965}_t \\ &+ \cdots + \beta_{13}\text{year 2005}_t + u_i + e_{it},\end{aligned}$$

$$\begin{aligned}&\text{Carbon Dioxide Emissions per capita}_{it} \text{ or} \\ &\text{Carbon Dioxide Emissions per GDP}_{it} = \\ &\qquad \beta_1\text{GDP per capita}_{it} + \beta_2\text{Urban Population}_{it} \\ &\qquad + \beta_3\text{Trade}_{it} + \beta_4\text{year 1965}_t + \cdots + \beta_{12}\text{year 2005}_t \\ &\qquad + u_i + e_{it}.\end{aligned}$$

Thus, model A for all three outcomes includes GDP per capita, urban population, trade as a percentage of GDP, and the period-specific intercepts (i.e., $\beta_5\text{year 1965}_t + \cdots + \beta_{13}\text{year 2005}_t$) as well as the country-specific intercepts and the disturbance term unique to each country at each point in time. For the analysis of total carbon dioxide emissions, model A also includes total population as a predictor.

The second model for all three outcomes, labeled as model B in tables 2–4, builds on model A but also includes the interaction between GDP per capita and the dummy variable for less developed countries (labeled LDC). We remind readers that the time-invariant dummy variable for less developed countries is perfectly correlated with the country-specific fixed effects and thus is excluded as a main effect in this estimated model for all three outcomes (Allison 2009). Model B is as follows:

$$\begin{aligned}\text{Total Carbon Dioxide Emissions}_{it} = \\ &\beta_1\text{GDP per capita}_{it} + \beta_2\text{Urban Population}_{it} \\ &+ \beta_3\text{Trade}_{it} + \beta_4\text{Population}_{it} + \beta_5\text{year 1965}_t \\ &+ \cdots + \beta_{13}\text{year 2005}_t + \beta_{14}\text{GDP per capita}_{it} \times \text{LDC}_i \\ &+ u_i + e_{it},\end{aligned}$$

$$\begin{aligned}&\text{Carbon Dioxide Emissions per capita}_{it} \text{ or} \\ &\text{Carbon Dioxide Emissions per GDP}_{it} = \\ &\qquad\beta_1\text{GDP per capita}_{it} + \beta_2\text{Urban Population}_{it} \\ &\qquad+ \beta_3\text{Trade}_{it} + \beta_4\text{year 1965}_t + \cdots + \beta_{12}\text{year 2005}_t \\ &\qquad+ \beta_{13}\text{GDP per capita}_{it} \times \text{LDC}_i + u_i + e_{it}.\end{aligned}$$

The third model, labeled model C in tables 2–4, builds on model A and also includes the interactions between GDP per capita and the dummy variables for each time point. For each outcome we estimate model C for the overall data set as well as the two data sets restricted to only developed countries and only less developed countries.[20] Model C is as follows:

$$\begin{aligned}\text{Total Carbon Dioxide Emissions}_{it} = \\ &\beta_1\text{GDP per capita}_{it} + \beta_2\text{Urban Population}_{it} \\ &+ \beta_3\text{Trade}_{it} + \beta_4\text{Population}_{it} + \beta_5\text{year 1965}_t \\ &+ \cdots + \beta_{13}\text{year 2005}_t + \beta_{14}\text{GDP per capita}_{it} \times \text{year 1965}_t \\ &+ \cdots + \beta_{22}\text{GDP per capita}_{it} \times \text{year 2005}_t + u_i + e_{it},\end{aligned}$$

[20] We note that elsewhere in analyses of the total sample we include three-way interactions between development, time, and the LDC dummy variable as well as all necessary two-way interactions. The results are substantively consistent with the reported finding for the analyses conducted separately for the sample of developed countries and the sample of less developed countries. For purposes of parsimony and ease of interpretation (Firebaugh 2008) as well as to minimize extreme multicollinearity common with three-way interactions, we prefer to report and focus on the two-way interaction models estimated for the full sample and the two restricted samples (see also Jorgenson and Clark 2010). We thank a reviewer for also suggesting this approach.

$$
\begin{aligned}
&\text{Carbon Dioxide Emissions per capita}_{it} \text{ or} \\
&\text{Carbon Dioxide Emissions per GDP}_{it} = \\
&\qquad \beta_1\text{GDP per capita}_{it} + \beta_2\text{Urban Population}_{it} \\
&\qquad + \beta_3\text{Trade}_{it} + \beta_4\text{year 1965}_t + \cdots + \beta_{12}\text{year 2005}_t \\
&\qquad + \beta_{13}\text{GDP per capita}_{it} \times \text{year 1965}_t \\
&\qquad + \cdots + \beta_{21}\text{GDP per capita}_{it} \times \text{year 2005}_t + u_i + e_{it}.
\end{aligned}
$$

RESULTS

Tables 2, 3, and 4 report the model estimates.[21] Findings for the total emissions analyses are presented in table 2, table 3 provides the results of the per capita emissions analyses, and table 4 presents the findings for the analyses of emissions per unit of production (i.e., per unit of GDP).[22] We remind readers that all models include unreported unit-specific and period-specific intercepts, which commonly lead to relatively high R-square values.

The results of the first total emissions model (model A) in table 2 indicate that the linear effects of GDP per capita, total population, urban population, and trade are all positive and statistically significant. In the second model (model B), we find that the linear effect of GDP per capita on total

[21] Employing GDP per capita as an independent variable in time-series or panel analyses with relatively large numbers of time points can lead to spurious results due to unit root problems. As shown by Wagner (2008), prior time-series research in environmental economics that suggests the existence of EKC distributions is plagued by unit roots and thus spurious results. While the current study's overall data set consists of relatively larger numbers of cases and smaller numbers of time points, the same estimation problems could apply here as well. Thus, we also estimate first-difference (FD) baseline models with the same substantive predictors as in model A of each outcome to assess whether the PW model estimates are spurious for such reasons. The results of the FD models are reported in app. table A6. FD models are commonly used to correct for nonstationarity (Cameron and Trivedi 2009). The consequences of not first-differencing when there is a unit root problem are serious (spurious results), whereas if the data are differenced when there is no unit root, the main consequence is only loss of efficiency because of the moving average error created by the differencing (Kennedy 2008). If the FD model estimates are consistent with the PW model estimates, we can assume that the analyses are not biased because of nonstationarity. The results of the FD baseline models are entirely consistent with the reported PW model A estimates.

[22] Diagnostics suggest that the analyses contain no overly influential cases.

TABLE 2
UNSTANDARDIZED COEFFICIENTS FOR THE REGRESSION OF TOTAL CARBON DIOXIDE EMISSIONS, 1960–2005: PW REGRESSION MODEL ESTIMATES WITH PCSE AND AN AR(1) CORRECTION

			MODEL C		
	MODEL A	MODEL B	All	DCs	LDCs
Total population	1.554*** (14.29)	1.533*** (12.04)	1.328*** (9.92)	1.222*** (9.87)	1.471*** (8.54)
Urban population	.021*** (5.95)	.021*** (5.96)	.021*** (5.82)	.012*** (3.85)	.020*** (4.21)
Trade	.003*** (4.24)	.003*** (4.24)	.003*** (4.22)	−.004*** (4.20)	.004*** (4.28)
GDP per capita	.926*** (14.82)	.903*** (9.22)	1.023*** (14.51)	.986*** (11.99)	1.003*** (9.97)
GDP per capita × LDCs		.029 (.32)			
Interactions with time:					
GDP per capita × 1965			−.010 (.51)	.002 (.70)	−.012 (.32)
GDP per capita × 1970			−.027 (1.12)	.008 (1.81)	−.051 (1.05)
GDP per capita × 1975			−.046 (1.67)	−.002 (.40)	−.046 (.90)
GDP per capita × 1980			−.092** (3.09)	−.005 (.88)	−.105 (1.95)
GDP per capita × 1985			−.095** (2.99)	−.020** (2.91)	−.103 (1.84)
GDP per capita × 1990			−.091** (2.69)	−.029*** (3.88)	−.099 (1.76)
GDP per capita × 1995			−.101** (2.91)	−.031*** (3.89)	−.106 (1.88)
GDP per capita × 2000			−.111** (3.03)	−.037*** (4.15)	−.110 (1.91)
GDP per capita × 2005			−.104** (2.74)	−.044*** (4.73)	−.097 (1.65)
R^2 overall	.986	.986	.987	.997	.980
N	860	860	860	220	640
Estimated coefficients	99	100	108	44	86

NOTE.—Absolute values of z-ratios are in parentheses; all models include unreported unit-specific and period-specific intercepts.
* $P < .05$ (two-tailed).
** $P < .01$.
*** $P < .001$.

emissions does not vary between the developed countries and the less developed countries. More specifically, the interaction between GDP per capita and less developed countries is nonsignificant.

The findings of model C for the overall sample suggest that the magnitude of economic development's effect on total emissions varies through time. The interactions between GDP per capita and each time point from 1980 through 2005 are negative and statistically significant. These results provide evidence of a relative decoupling between total emissions and economic development, where the estimated coefficient for GDP per capita decreased from a value of 1.023 in 1960 to a value of 0.919 in 2005.

TABLE 3
UNSTANDARDIZED COEFFICIENTS FOR THE REGRESSION OF PER CAPITA CARBON DIOXIDE EMISSIONS, 1960–2005: PW REGRESSION MODEL ESTIMATES WITH PCSE AND AN AR(1) CORRECTION

			Model C		
	Model A	Model B	All	DCs	LDCs
Urban population	.014***	.015***	.014***	.008**	.012***
	(9.81)	(10.87)	(9.95)	(3.11)	(7.18)
Trade	.001*	.001*	.001*	−.002***	.001***
	(2.18)	(2.21)	(2.35)	(3.62)	(3.36)
GDP per capita	.547***	.737***	.467***	.757***	.388***
	(20.81)	(19.59)	(16.57)	(13.14)	(11.05)
GDP per capita × LDCs		−.230***			
		(7.01)			
Interactions with time:					
GDP per capita × 1965			.035***	.006*	.026
			(4.52)	(2.40)	(1.86)
GDP per capita × 1970			.071***	.016***	.044*
			(7.19)	(4.44)	(2.55)
GDP per capita × 1975			.072***	.016**	.071***
			(6.54)	(2.68)	(3.82)
GDP per capita × 1980			.076***	.013*	.088***
			(6.61)	(2.56)	(4.59)
GDP per capita × 1985			.063***	.005	.077***
			(5.29)	(.81)	(3.85)
GDP per capita × 1990			.064***	.001	.077***
			(5.16)	(.19)	(3.84)
GDP per capita × 1995			.060***	.003	.069***
			(4.79)	(.43)	(3.47)
GDP per capita × 2000			.065***	.001	.076***
			(5.16)	(.17)	(3.84)
GDP per capita × 2005			.068***	−.002	.083***
			(5.29)	(.32)	(4.14)
R^2 overall	.941	.941	.942	.916	.887
N	860	860	860	220	640
Estimated coefficients	98	99	107	43	85

NOTE.—Absolute values of z-ratios are in parentheses; all models include unreported unit-specific and period-specific intercepts.
* $P < .05$ (two-tailed).
** $P < .01$.
*** $P < .001$.

However, the values of the multiple statistically significant interactions paint a slightly more complex story. With a coefficient of −0.092, the first statistical evidence of decoupling occurred in 1980 relative to 1960. The significant interaction for 1985 is −0.095, for 1990 it changes to −0.091, and it yields a value of −0.101 in 1995. For 2000 the interaction has a value of −0.111 and then modestly shifts to a value of −0.104 in 2005. Thus, while the overall beginning and endpoints indicate a small to moderate decrease in the effect of economic development on total emissions, it appears that within this general trend of relative decoupling there were slight "minicycles" of relative decoupling followed by relative intensification, the latter of which happened as late as between 2000 and 2005.

TABLE 4
UNSTANDARDIZED COEFFICIENTS FOR THE REGRESSION OF CARBON DIOXIDE EMISSIONS PER GDP, 1960–2005: PW REGRESSION MODEL ESTIMATES WITH PCSE AND AN AR(1) CORRECTION

			Model C		
	Model A	Model B	All	DCs	LDCs
Urban population	.0001*** (6.50)	.0001*** (5.78)	.0001*** (5.67)	.0001*** (4.91)	.0001*** (4.20)
Trade	.0001 (1.56)	.0001 (1.54)	.0001 (1.83)	−.0001*** (4.71)	.0001 (1.95)
GDP per capita	−.0005*** (8.21)	−.0005*** (4.14)	−.0005*** (7.03)	.0001 (.05)	−.0002* (2.36)
GDP per capita × LDCs		−.0001 (.36)			
Interactions with time:					
GDP per capita × 1965			−.0001 (.95)	−.0001 (.46)	−.0001 (.85)
GDP per capita × 1970			.0001 (.14)	.0001 (.82)	.0001 (.34)
GDP per capita × 1975			−.0001 (.32)	−.0001 (1.51)	.0001 (.43)
GDP per capita × 1980			.0001 (.08)	−.0001 (1.73)	.0001 (1.26)
GDP per capita × 1985			−.0001 (1.03)	−.0001*** (3.75)	.0001 (.51)
GDP per capita × 1990			−.0001 (.71)	−.0001*** (4.52)	.0001 (1.01)
GDP per capita × 1995			−.0001 (.85)	−.0001*** (4.45)	.0001 (.98)
GDP per capita × 2000			−.0001 (1.54)	−.0001*** (4.21)	−.0001 (.04)
GDP per capita × 2005			−.0001 (1.62)	−.0001*** (4.74)	−.0001 (.09)
R^2 overall	.683	.683	.680	.871	.696
N	860	860	860	220	640
Estimated coefficients	98	99	107	43	85

NOTE.—Absolute values of z-ratios are in parentheses; all models include unreported unit-specific and period-specific intercepts.
* $P < .05$ (two-tailed).
** $P < .01$.
*** $P < .001$.

Turning to the separate model C estimates for developed countries and less developed countries, we find notable differences. For the latter, all interactions between GDP per capita and time are nonsignificant. Thus, we find no evidence of a relative decoupling or intensification between total emissions and economic development in less developed countries. For the sample of only developed countries, the interactions between GDP per capita and multiple time points (i.e., 1985, 1990, 1995, 2000, 2005) are negative and statistically significant, and they increase successively in absolute value, thus exhibiting a pattern very similar to that in the analysis of the overall sample. In sum, it appears that the pattern of decoupling between total emissions and development observed for the combined sample is primarily driven by the shifting relationships between the outcome and GDP per capita for the developed countries.

When comparing 1960 to 2005, we find that the coefficient for GDP per capita for the sample of developed countries decreased from 0.986 to 0.942. For the significant interactions, with a coefficient of −0.020, the first statistical evidence of decoupling in the developed countries occurred in 1985 relative to 1960. The significant interaction for 1990 is −0.029, and for 1995 it slightly changes to −0.031. For 2000 the interaction is −0.037 and increases to −0.044 in 2005. Figure 1 provides the estimated effects of GDP per capita on total emissions for the two samples restricted to only developed countries and only less developed countries, 1960–2005.

We now turn to the analysis of per capita emissions reported in table 3. With one exception, model A and model B of per capita emissions yield results similar to those in the total emissions analyses. The linear effects of GDP per capita, urban population, and trade are all positive and statistically significant. However, in model B the effect of the interaction between GDP per capita and the dummy variable for less developed countries is negative and statistically significant. The linear effect of GDP per capita on per capita emissions is larger for the developed countries (coefficient = 0.737) than for the less developed countries (coefficient = 0.507).

In the estimated model C for the overall sample, the interactions between GDP per capita and time are all positive and statistically significant. When we focus on the beginning and endpoints of the period of study, the estimated coefficient for the effect of GDP per capita on per capita emissions increased from a value of 0.467 in 1960 to 0.535 in 2005, which suggests the opposite of decoupling and contradicts the arguments of ecological modernization theory. While these results highlight an overall increase in the size of the effect of GDP per capita on per capita emissions in 2005 relative to 1960, the significant interactions paint a more nuanced picture of these shifts. More specifically, from 1960 to 1980 the association between per capita emissions and development intensified, with the estimated effect of GDP per capita in 1980 being 0.543 and then declining to a value of 0.530 in 1985, slightly increasing to 0.531 in 1990, decreasing to 0.527 in 1995, and then increasing to 0.532 in 2000 and 0.535 in 2005.

However, the results of model C for the two samples of only developed countries and only less developed countries suggest different temporal-structural processes. For the latter, the interactions between GDP per capita and each time point for 1970–2005 are positive and statistically significant. Overall, for the sample of less developed countries, the coefficient for GDP per capita increased in value from 0.388 in 1960 to 0.471 in 2005. For the estimated model for only developed countries, while the beginning point (1960) and the endpoint (2005) suggest no statistically

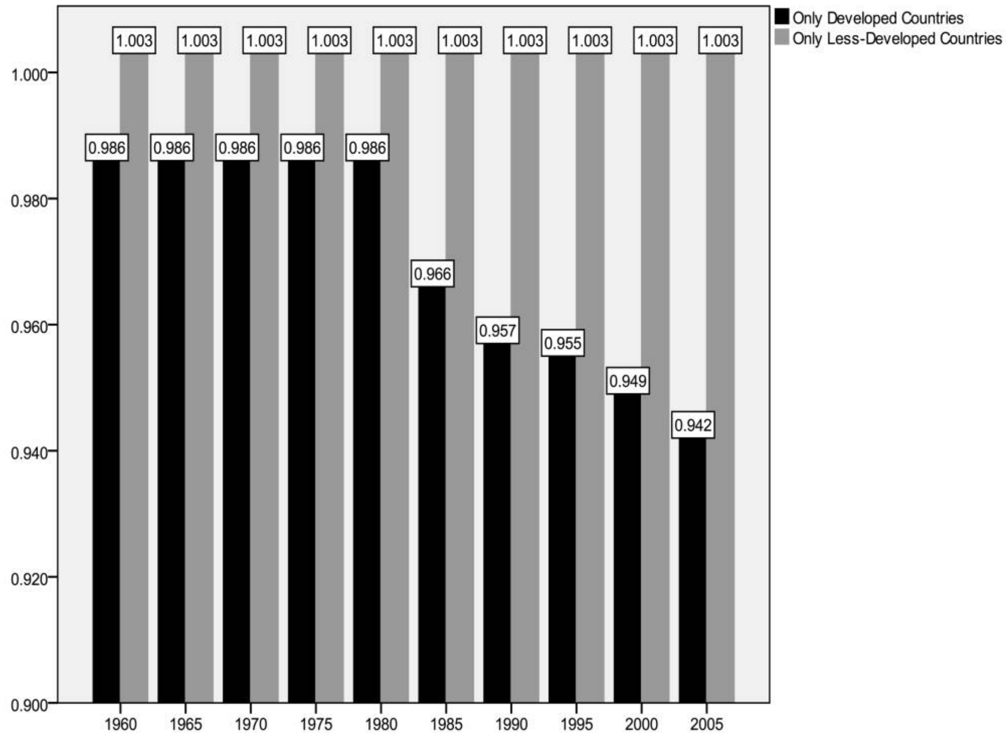

FIG. 1.—Estimated effects of GDP per capita on total carbon dioxide emissions

significant differences in the effect of GDP per capita on per capita emissions, the interactions between level of development and time are positive and statistically significant for the time points from 1965 to 1980. The size (absolute values) of the coefficients for the significant interactions increases successively from 1965 to 1970, remains the same in 1975, then slightly decreases in 1980 before becoming nonsignificant in 1985. Figure 2 presents the estimated effects of GDP per capita on per capita emissions for the two restricted samples.

Thus, it appears that in the sample of developed countries, a small cycle of minor intensification then decoupling occurred in the beginning of the period of study, where the effect of economic development on per capita emissions increased and then decreased. The latter suggests a relative decoupling from after 1970 until roughly 1980 and then a period of stability lasting until at least 2005, with the estimated effect of GDP per capita being the same in 2005 as in 1960. For the sample of less developed countries, model C reveals an overall temporal pattern of intensification in the relationship between per capita emissions and level of economic development, with the effect of GDP per capita increasing from 0.388 in 1960 to 0.471 in 2005. These dissimilarities between the estimates for model C for the two restricted samples underscore the importance in considering differences between the global North and the global South.

In the analysis of emissions per unit of production in table 4, the effect of the level of economic development in models A and B is negative and statistically significant, but the interaction between developed and less developed countries in model B is nonsignificant. Thus, it appears that in general, level of development has a negative linear effect on emissions per unit of production, but this negative effect does not differ for the developed and less developed countries included in the analyses. The effect of urban population is positive and statistically significant in all models, whereas the effect of trade is nonsignificant in all models except for the estimated model C for the sample restricted to developed countries, where it exhibits a significant negative effect.

The results of model C for the overall sample indicate that the interactions between GDP per capita and each time point are all nonsignificant, providing no evidence of relative decoupling or intensification. For the sample restricted to developed countries, findings for model C reveal negative and statistically significant interactions between GDP per capita and each time point from 1985 through 2005. However, for ease of interpretation these reported coefficients are rounded up (in absolute value) in table 4, each to a value of −0.0001. The actual values of the estimated coefficients for the significant interactions are quite small but suggest a slight statistical pattern of relative decoupling, with actual values of −0.0000148, −0.0000197, −0.0000205, −0.0000216, and −0.0000254.

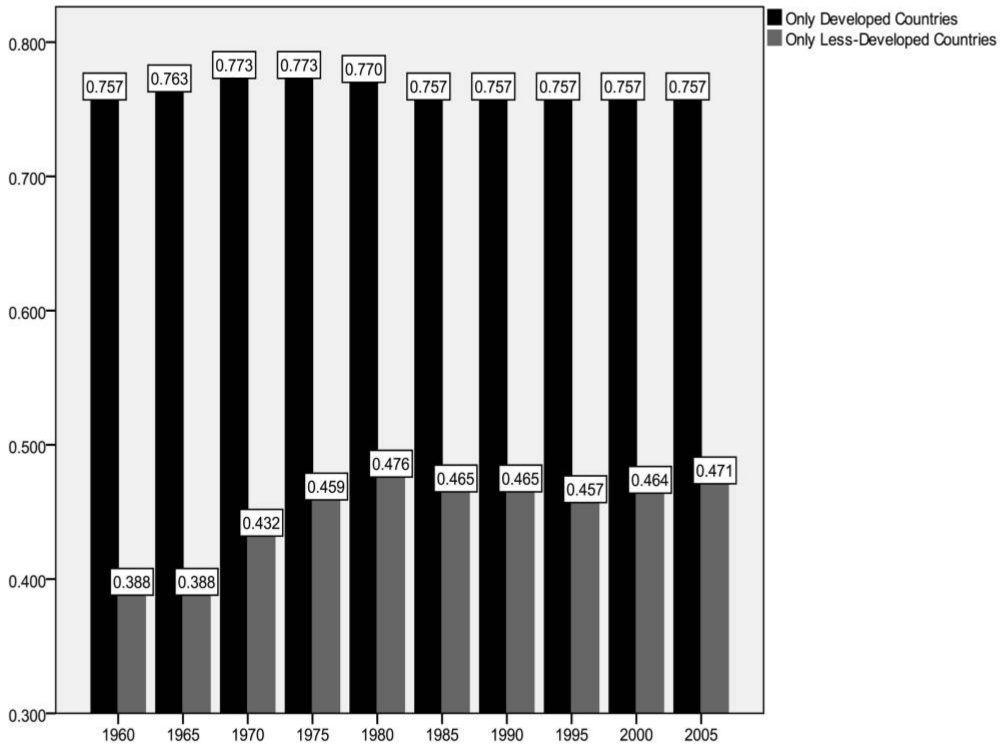

FIG. 2.—Estimated effects of GDP per capita on per capita carbon dioxide emissions

While this is suggestive of relative decoupling in a statistical sense, the estimated differences through time—we would argue—are small enough that one should be wary of concluding that they have great substantive importance. For the sample of only less developed countries, like the results for the overall sample, the estimated effects of all interactions between GDP per capita and time are nonsignificant, providing no evidence of relative intensification or decoupling.[23]

DISCUSSION AND CONCLUSION

This research addresses one of the most central themes in environmental sociology: the environment/economic development relationship. Within this central theme, propositional contestations exist between two dominant theories. The first theory, ecological modernization, posits that while economic development requires inputs and generates waste, both of which contribute to various forms of environmental problems, the magnitude of economic development's impact on the environment is likely to decrease through time, and such a decoupling is likely to occur first in developed countries. In contrast, the treadmill of production theory suggests that the national-level environmental impacts of economic development should remain stable or perhaps increase in magnitude through time, regardless of whether countries are relatively more developed or less developed. We evaluated these competing propositions by employing appropriate measurements and panel model estimation techniques to assess the temporal stability of the effect of economic development on anthropogenic carbon dioxide emissions measured by scale (total), intensity (per capita), and per unit of production (per unit of GDP) in cross-national contexts, and we also assessed the temporal stability of the effects in samples restricted to only developed countries and only less developed countries. Each theory considers all three measures of emissions as well as possible differences in their relationships with development for nations within the global North and the global South. As highlighted in the results section, the analyses yielded a number of findings with significant implications for both perspectives, especially the results of the analyses of the two restricted samples.

First, for total emissions it appears that the magnitude of economic development's positive effect decreased in developed countries, with the

[23] Given the lack of evidence of noteworthy temporal shifts in the relationships between emissions per unit of GDP and level of development for either restricted sample (or the overall sample), we consider it unnecessary to present a figure that provides the estimated effects of GDP per capita for each time point for the developed countries and less developed countries.

overall effect of economic development on total emissions being smaller in magnitude at the endpoint of the period of study relative to the starting point. Contrarily, the magnitude of economic development's effect on total emissions in less developed countries remained strong and statistically time invariant for the entire 1960–2005 period of study. Second, for per capita emissions the results suggest that in developed countries the effect of economic development slightly increased successively from 1965 through 1970, remained stable through 1975, followed by a relative decoupling of the relationship through the early 1980s, and ended with a period of relative temporal stability from at least 1985 through 2005, with the effect of GDP per capita in 2005 being the same as in 1960. For less developed countries, the results suggest the opposite of decoupling. Beginning in 1970, the effect of GDP per capita started increasing and continued to do so through at least 1980, followed by a slight declining trend from 1985 through 1995 and then successive relative increases in 2000 and 2005. Even with these minicycles, the overall trend from 1960 through 2005 for the sample of less developed countries is one of relative intensification. Third, the analyses of ecoefficiency—in the context of emissions per unit of GDP—resulted in mostly nonsignificant effects of the interactions between economic development and time for developed countries and less developed countries as well as for the overall sample. The few significant interactions in the final model for only the developed countries suggest a very slight pattern of relative decoupling beginning in 1985 and continuing through 2005.

The mostly null findings for the final set of analyses call into question the practice—especially within the policy literature—of focusing solely or primarily on emissions per unit of production. While we have no immediate recommendations for how to better measure ecoefficiency and to subsequently and more effectively assess its relationship to economic growth in macro-comparative contexts, we suggest that actors involved in developing and implementing climate change policies aimed at reducing anthropogenic greenhouse gas emissions should, at minimum, evaluate emissions measured by scale, intensity, and per unit of production. Just as important, given that research often guides policy, we encourage others who study these and related topics to take more comprehensive approaches when assessing the human causes of growth in and variation between national-level emissions. The diversity of our findings across the three measures of carbon dioxide emissions underscores the necessity of doing so. Further, our analysis of ecoefficiency and economic development by itself provides little assistance in resolving the long-standing theoretical debates in sociology concerning the environmental challenges and consequences of development. But it does suggest that taking into account other environmental measures (e.g., total emissions, per capita emissions) is important for assessing ecological sustainability as well as for being able to conduct balanced, rigorous, and inclusive hypothesis testing.

While we find some overall evidence of a relative decoupling between economic development and emissions measured by scale in developed countries and, contrarily, evidence of a temporal intensification of the relationship between per capita emissions and economic development in less developed countries as well as a constant strong relationship between total emissions and development, the observed changes in the magnitude of the relationships are relatively minor from sustainability, international inequality, and climate change perspectives. As indicated by the mean values for 1960 and 2005 reported in appendix table A1, there has been some convergence in the average level of total emissions between the global North and the global South. However, if we remove China and India from the sample of less developed countries, the pattern of convergence largely disappears. And as shown by table A1, major differences in the contributions of the per capita levels of emissions between developed countries and less developed countries remain, whereas the results of model B for per capita emissions highlight the substantial general discrepancies in the size of the effects of GDP per capita for developed countries relative to less developed countries. These differences highlight the developed countries' disproportionate contributions to anthropogenic emissions and thus climate change, as well as the stark global North/global South environmental inequality divide, both of which greatly complicate negotiations and implementations of mitigation and adaptation strategies (Roberts and Parks 2007). Developed countries are disproportionately responsible for the historic accumulation of carbon dioxide in the atmosphere, which is generating changes in climate that are creating significant challenges for people in the global South. Less developed countries tend to have a greater reliance on climate-sensitive sectors of production such as agriculture, they have more geographic exposure to climate changes, and they are more likely to have relatively weak infrastructure. Thus, these nations confront more extreme threats due to droughts, floods due to the melting of mountain glaciers, general changes in hydrologic cycles, and rising sea levels. Here climate change threatens the basic conditions of well-being, which makes alleviating poverty and other social problems even more difficult (Stern 2007).

Overall, our findings suggest that both the ecological modernization theory and the treadmill of production theory include a number of shortcomings as far as addressing the structural relationships between environmental harms and economic development. We argue that both orientations would greatly benefit from incorporating arguments and evidence from other bodies of macrosociological inquiry that focus explicitly on shifts in the organization of production and the structure of international trade within the world economy.[24] For example, the world economy as a whole experienced a recent upswing in the globalization of foreign direct investment, which highlights the growing transnationalization of production (Chase-Dunn and Jorgenson 2007). While such an upswing is evident globally, other research links growth in the total, per capita, and per unit of production carbon dioxide emissions of less developed countries to increases in secondary-sector foreign investment, but the same associations are nonexistent for developed countries (e.g., Jorgenson et al. 2007; Jorgenson 2009). In a related vein, major traditions of research in the sociology of development have debated how and the extent to which foreign direct investment contributes to economic development in less developed countries. Within this debate, it is recognized by all sides that foreign investment contributes to economic development in less developed countries—at least to some extent (e.g., Firebaugh 1992; Dixon and Boswell 1996). It is likely that the results of this study are partially attributable to the growth of carbon-intensive manufacturing in less developed countries via the transnationalization of production (Robinson 2004; Mahutga and Smith 2011). Neither the treadmill of production theory nor the ecological modernization theory adequately recognizes the role that this form of economic globalization plays in the various environment/development associations. Both perspectives need to refine their framing to capture how global economic relationships influence patterns of environmental harms differently in the global South and the global North.

Further, as we mentioned in the introduction, the world economy experienced a recent upsurge in the globalization of trade (Chase-Dunn et al. 2000). Research in the emergent ecologically unequal exchange tradition indicates that during this upsurge, less developed countries with a greater reliance or focus on manufacturing exports to developed countries exhibit higher rates of growth in total and per capita carbon dioxide emissions (Roberts and Parks 2007; Stretesky and Lynch 2009; Jorgenson 2012).[25] And as in foreign direct investment, research links economic development in less developed countries to trade openness, and the latter generally includes growth in manufacturing exports (e.g., Gilpin 2001; Kentor and Boswell 2003). However, like the transnational organization

[24] In a related vein, Schwom (2009) argues that to better understand middle-level human/environment dynamics, such perspectives could also benefit from engaging key insights within the field of organizational sociology (see also Dunlap 2010).

[25] In the reported models we control for overall trade as a percentage of GDP, which exhibits positive and statistically significant effects on all three outcomes. While this measure does not capture the relational characteristics of trade, such results are generally consistent with the theoretical propositions of and empirical findings from the bodies of scholarship within the ecologically unequal exchange tradition.

of production, particularly in the context of foreign direct investment in carbon-intensive sectors, the ecological modernization and treadmill approaches both fail to consider with reasonable depth or precision the ways in which the structure of international trade influences emissions/economic development relationships and how such world economic processes could partially shape the observed environment/economy decoupling in some nations as well as the simultaneous intensification or time-invariant associations in others.[26]

We conclude that world-economic shifts are important considerations when characterizing the complex environment/economy nexus. While the ecological modernization theory and the treadmill of production theory both assume that the current economic system is predicated on growth, they differ on the magnitude of environmental harms associated with continual development. Both perspectives need further refinement to better explain in generalizable contexts the dynamics of economic development and its environmental impacts. Shifts in the sites of production are facilitated by advancements in transportation, communication, and other technologies (Bunker and Ciccantell 2005; Harvey 2006; Pellow 2007). Transnational firms build new or purchase existing facilities in less developed countries—such as in Asia and Latin America—to take advantage of lower production costs and more permissive environmental laws (Leonard 1988; Dick 2010). This shift in production has contributed to the increase of carbon emissions in less developed countries, even though much of the products will be consumed in developed countries (Roberts and Parks 2007; Jorgenson and Clark 2009). The modest, relative decou-

[26] While we suggest that these other streams of research help to explain the diverse results of the current study, their causal explanations vary. From a more critical perspective, the foreign investment and trade effects on emissions found in other studies are illustrative of developed countries and the firms headquartered within their borders outsourcing and off-shoring environmentally unfriendly export-oriented manufacturing to less developed countries (e.g., Clapp and Dauvergne 2005). Such processes could give the appearance of ecological modernization taking place in developed countries but ultimately be part and parcel of the globalizing treadmill of production, which allows for forms of environmental cost shifting. Or, as suggested by variants of the pollution halo hypothesis in environmental economics (e.g., Cole, Elliott, and Strobl 2008; Perkins and Neumayer 2009) and consistent with a globally oriented ecological modernization perspective, the diffusion of more environmentally friendly forms of manufacturing from developed to less developed countries with growing export-oriented economies through spillover effects and technology transfers via transnational corporations is a process that requires a great deal of time for the benefits to be recognized at aggregated levels. From this less critical perspective, one could argue that the results of the current study are consistent with the notion that more time is needed for the intensification of the emissions/development relationship in less developed countries to shift course and perhaps transition into a process of modest decoupling and ecological modernization, analogous to what has taken place in the global North in recent decades.

pling between total emissions and development in countries within the global North may in fact be linked to two sets of structural processes in countries within the global South: (1) the intensification of the relationship between per capita emissions and economic development and (2) the temporal stability in the strong relationship between total emissions and economic development.

The dynamics of the global economic system demand that a conceptualization of shifts is incorporated into our assessment of environment/economic development relationships. It should be made clear that a relative (as opposed to an absolute) decoupling of this relationship, while important, still indicates an overall increase in total carbon dioxide emissions. In other words, the growth rate of carbon dioxide emissions is not as large as the economic growth rate in such situations. As a result, even a relative decoupling—to the extent that it exists—does not diminish the ecological challenge that confronts society, given the ongoing accumulation of carbon dioxide in the atmosphere. The human dimensions of global climate change are rooted in addressing the impacts of economic development. Our proposed refinements of both the ecological modernization theory and the treadmill of production theory as well as rigorous empirical work are central ways in which comparative sociology can contribute to our collective understanding of these fundamental society/nature relationships.

APPENDIX

TABLE A1
Mean Values and Growth Rates for GDP per Capita and All Three Measures of Carbon Dioxide Emissions, 1960–2005

	GDP per Capita			Total CO_2			CO_2 per Capita			CO_2 per GDP		
	All	DCs	LDCs	All	DCs	LDCs	All	DCs	LDCs	All	DCs	LDCs
Mean values:												
1960	2,734	8,124	881	71,809,465	216,250,363	22,157,906	1.876	5.324	.691	.0008	.0006	.0009
2005	7,619	24,833	1,702	253,933,593	512,454,727	165,066,953	3.765	10.190	1.556	.0008	.0005	.0010
Mean growth rates (%):												
1960–65	18	21	11	16	24	−8	20	22	12	−7	3	−9
1965–70	19	21	14	32	31	40	25	28	19	7	7	7
1970–75	13	13	12	12	6	38	6	2	19	−1	−8	1
1975–80	12	13	10	15	8	36	10	8	17	7	−3	9
1980–85	6	9	−4	3	−3	19	−5	−6	−3	−6	−12	−5
1985–90	11	13	1	15	9	27	7	6	8	7	−4	10
1990–95	7	7	6	15	7	31	4	5	2	4	−2	5
1995–2000	14	15	10	10	9	12	5	5	4	−10	−8	−10
2000–2005	8	7	12	18	4	40	4	1	10	−2	−7	−1

Note.—"All" refers to all nations included in data set, "DCs" refers to the nations in the data set that are categorized as developed, and "LDCs" refers to the nations in the data set that are categorized as less developed. Mean growth rates refer to the percentage change in mean values for the specified five-year period. For ease of interpretation, all percentage scores are rounded. Mean values of GDP per capita are rounded to the nearest dollar and measured in constant 2000 U.S. dollars. Mean values of total carbon dioxide (CO_2) are reported in metric tons and slightly rounded for ease of interpretation. Mean values of CO_2 per capita are reported in metric tons per person and slightly rounded for ease of interpretation. Mean values of CO_2 per GDP are reported in metric tons per dollar of GDP and slightly rounded for ease of interpretation.

TABLE A2
Descriptive Statistics

	All Countries		Developed Countries		Less Developed Countries	
	Mean	SD	Mean	SD	Mean	SD
Total CO_2	16.309	2.449	18.501	1.452	15.554	2.260
CO_2 per capita	.997	.857	2.149	.490	.601	.539
CO_2 per GDP	.0009	.0008	.0006	.0003	.0009	.0010
GDP per capita	7.353	1.602	9.538	.613	6.601	1.054
GDP per capita × LDCs	4.913	3.022				
GDP per capita 1965	.708	2.174	.905	2.729	.640	1.945
GDP per capita 1970	.722	2.217	.927	2.792	.651	1.979
GDP per capita 1975	.732	2.251	.941	2.834	.660	2.009
GDP per capita 1980	.741	2.278	.954	2.872	.668	2.032
GDP per capita 1985	.742	2.282	.962	2.897	.667	2.026
GDP per capita 1990	.745	2.295	.976	2.938	.665	2.024
GDP per capita 1995	.746	2.304	.984	2.960	.664	2.026
GDP per capita 2000	.756	2.334	.998	3.004	.672	2.051
GDP per capita 2005	.765	2.362	1.006	3.027	.682	2.081
Total population	16.331	1.350	16.508	1.202	16.270	1.393
Urban population	46.574	2.401	70.357	1.439	38.399	2.103
Trade as % of GDP	58.042	3.199	60.800	3.150	57.094	3.213

Note.—CO_2 refers to carbon dioxide emissions. All emissions, GDP per capita, and total population measures are logged (ln). For all countries, $N = 860$; for developed countries, $N = 220$; and for less developed countries, $N = 640$.

TABLE A3

CORRELATION MATRICES: ALL COUNTRIES (N = 860)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Total CO_2																
2. CO_2 per capita	.781															
3. CO_2 per GDP	.359	.114														
4. GDP per capita	.687	.916	−.147													
5. GDP per capita × LDCs	−.373	−.622	.173	−.592												
6. GDP per capita 1965	−.057	−.018	−.031	.005	−.055											
7. GDP per capita 1970	−.007	.031	−.012	.035	−.048	−.106										
8. GDP per capita 1975	.024	.054	−.014	.059	−.040	−.106	−.106									
9. GDP per capita 1980	.059	.082	.003	.078	−.035	−.106	−.106	−.106								
10. GDP per capita 1985	.065	.073	−.016	.082	−.038	−.106	−.106	−.106	−.106							
11. GDP per capita 1990	.088	.093	.004	.093	−.041	−.106	−.106	−.106	−.106	−.106						
12. GDP per capita 1995	.114	.112	.012	.101	−.042	−.106	−.106	−.105	−.105	−.105	−.105					
13. GDP per capita 2000	.131	.123	−.015	.122	−.036	−.106	−.106	−.105	−.105	−.105	−.105	−.105				
14. GDP per capita 2005	.148	.135	−.021	.140	−.027	−.106	−.106	−.106	−.105	−.105	−.105	−.105	−.105			
15. Total population	.713	.197	.369	.071	−.072	−.080	−.054	−.030	−.006	.018	.042	.064	.082	.100		
16. Urban population	.659	.814	−.033	.857	−.362	−.055	−.015	.021	.053	.081	.110	.136	.161	.185	.094	
17. Trade as % of GDP	−.051	.171	−.010	.182	.013	−.129	−.096	−.016	.029	−.003	.009	.075	.155	.205	−.383	.181

TABLE A4

CORRELATION MATRICES: DEVELOPED COUNTRIES ($N = 220$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Total CO_2															
2. CO_2 per capita	.605														
3. CO_2 per GDP	.297	.402													
4. GDP per capita	.385	.716	−.321												
5. GDP per capita 1965	−.105	−.174	.107	−.242											
6. GDP per capita 1970	−.027	−.017	.165	−.130	−.111										
7. GDP per capita 1975	−.002	.012	.087	−.054	−.111	−.111									
8. GDP per capita 1980	.027	.063	.062	.013	−.111	−.111	−.111								
9. GDP per capita 1985	.024	.035	−.043	.058	−.111	−.111	−.111	−.111							
10. GDP per capita 1990	.049	.079	−.076	.131	−.111	−.111	−.111	−.111	−.111						
11. GDP per capita 1995	.071	.114	−.088	.171	−.111	−.111	−.111	−.111	−.111	−.111					
12. GDP per capita 2000	.089	.144	−.142	.250	−.111	−.111	−.111	−.111	−.111	−.111	−.111				
13. GDP per capita 2005	.101	.151	−.186	.291	−.111	−.111	−.111	−.111	−.111	−.111	−.111	−.111			
14. Total population	.913	.230	.169	.092	−.039	−.025	−.010	.001	.008	.017	.028	.036	.046		
15. Urban population	.281	.619	.171	.508	−.146	−.075	−.022	.018	.047	.077	.105	.128	.149	.021	
16. Trade as % of GDP	−.333	.181	−.135	.275	−.172	−.115	−.05	.027	.059	.004	.049	.202	.207	−.503	.255

TABLE A5

CORRELATION MATRICES: LESS DEVELOPED COUNTRIES (N = 640)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Total CO_2															
2. CO_2 per capita	.605														
3. CO_2 per GDP	.297	.402													
4. GDP per capita	.385	.716	−.321												
5. GDP per capita 1965	−.105	−.174	.107	−.242											
6. GDP per capita 1970	−.027	−.017	.165	−.130	−.111										
7. GDP per capita 1975	−.002	.012	.087	−.054	−.111	−.111									
8. GDP per capita 1980	.027	.063	.062	.013	−.111	−.111	−.111								
9. GDP per capita 1985	.024	.035	−.043	.058	−.111	−.111	−.111	−.111							
10. GDP per capita 1990	.049	.079	−.076	.131	−.111	−.111	−.111	−.111	−.111						
11. GDP per capita 1995	.071	.114	−.088	.171	−.111	−.111	−.111	−.111	−.111	−.111					
12. GDP per capita 2000	.089	.144	−.142	.250	−.111	−.111	−.111	−.111	−.111	−.111	−.111				
14. Total population	.777	.220	.429	.004	−.106	−.076	−.045	−.014	.017	.049	.076	.099	.120		
15. Urban population	.545	.735	.087	.844	−.100	−.056	−.012	.031	.067	.105	.140	.176	.210	.068	
16. Trade as % of GDP	−.041	.224	.010	.235	−.116	−.094	−.001	.026	−.037	.007	.085	.132	.205	−.356	.173

TABLE A6
UNSTANDARDIZED COEFFICIENTS FOR THE REGRESSION OF ALL THREE CARBON DIOXIDE EMISSIONS MEASURES, 1960–2005: FIRST-DIFFERENCE MODEL ESTIMATES

	Total Emissions	Per Capita Emissions	Emissions per GDP
GDP per capita	.650***	.328***	−.0004***
	(11.65)	(14.61)	(6.45)
Total population	1.433***		
	(8.65)		
Urban population ...	.022***	.015***	.0001***
	(4.21)	(7.40)	(3.59)
Trade	.002***	.001*	.0001
	(3.46)	(2.11)	(1.55)
R^2 overall	.269	.293	.062
N	774	774	774

NOTE.—Absolute values of t-ratios are in parentheses; models are estimated for samples of both developed and less developed countries.
* $P < .05$ (two-tailed).
** $P < .01$.
*** $P < .001$.

REFERENCES

Alderson, Arthur, and Jason Beckfield. 2004. “Power and Position in the World City System.” *American Journal of Sociology* 109:811–51.
Allison, Paul. 2009. *Fixed Effects Regression Models*. Thousand Oaks, Calif.: Sage.
Andersen, Mikael. 2002. “Ecological Modernization or Subversion? The Effect of Europeanization on Eastern Europe.” *American Behavioral Scientist* 45:1394–1416.
Argawal, Anil, and Sunita Narain. 1991. *Global Warming in an Unequal World*. New Delhi: Centre for Science and Environment.
Baum, Christopher. 2006. *An Introduction to Modern Econometrics Using Stata*. College Station, Tex.: Stata Press.
Beck, Nathaniel, and Jonathan Katz. 1995. “What to Do (and Not Do) with Time-Series Cross-Section Data.” *American Political Science Review* 89:634–47.
Beckfield, Jason. 2003. “Inequality in the World Polity: The Structure of International Organization.” *American Sociological Review* 68:401–24.
Bollen, Kenneth A., and Jennie E. Brand. 2010. “A General Panel Model with Random and Fixed Effects: A Structural Equations Approach.” *Social Forces* 89 (1): 1–34.
Brady, David, Yunus Kaya, and Jason Beckfield. 2007. “Reassessing the Effect of Economic Growth on Well-Being in Less-Developed Countries, 1980–2003.” *Studies in Comparative International Development* 42:1–35.
Bunker, Stephen. 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.
Bunker, Stephen, and Paul Ciccantell. 2005. *Globalization and the Race for Resources*. Baltimore: Johns Hopkins University Press.
Cameron, Colin, and Pravin Trivedi. 2009. *Microeconometrics Using Stata.* College Station, Tex.: Stata Press.
Chase-Dunn, Christopher, and Andrew Jorgenson. 2007. “Trajectories of Trade and

Investment Globalization." Pp. 165–84 in *Frontiers of Globalization Research*, edited by Ino Rossi. New York: Springer.
Chase-Dunn, Christopher, Yukio Kawano, and Benjamin Brewer. 2000. "Trade Globalization since 1795: Waves of Integration in the World-System." *American Sociological Review* 65:77–95.
Clapp, Jennifer, and Peter Dauvergne. 2005. *Paths to a Green World: The Political Economy of the Global Environment*. Cambridge, Mass.: MIT Press.
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 (1): 93–98.
Clark, Brett, and Richard York. 2005*a*. "Carbon Metabolism: Global Capitalism, Climate Change, and the Biospheric Rift." *Theory and Society* 34:391–428.
———. 2005*b*. "Dialectical Materialism and Nature: An Alternative to Economism and Deep Ecology." *Organization and Environment* 18 (3): 318–37.
Cole, Matthew, Robert Elliott, and Eric Strobl. 2008. "The Environmental Performance of Firms: The Role of Foreign Ownership, Training, and Experience." *Ecological Economics* 65:538–46.
Dick, Christopher. 2010. "Do Environmental Characteristics Influence Foreign Direct Investment Growth? A Cross-National Study, 1990–2000." *International Journal of Comparative Sociology* 51:192–210.
Dickens, Peter. 2004. *Society and Nature*. Cambridge: Polity.
Dietz, Thomas, and Linda Kalof. 1992. "Environmentalism among Nation-States." *Social Indicators Research* 26:253–66.
Dietz, Thomas, Eugene Rosa, and Richard York. 2007. "Driving the Human Ecological Footprint." *Frontiers in Ecology and the Environment* 5:13–18.
———. 2010. "Human Driving Forces of Global Change: Dominant Perspectives." Pp. 83–134 in *Human Footprints on the Global Environment: Threats to Sustainability*, edited by Eugene Rosa, Andreas Diekmann, Thomas Dietz, and Carlo Jaeger. Cambridge, Mass.: MIT Press.
———. 2012. "Environmentally Efficient Well-Being: Is There a Kuznets Curve?" *Applied Geography* 32:21–28.
Dinda, Soumyananda. 2004. "Environmental Kuznets Curve Hypothesis: A Survey." *Ecological Economics* 49:431–55.
Dixon, William, and Terry Boswell. 1996. "Dependency, Disarticulation, and Denominator Effects: Another Look at Foreign Capital Penetration." *American Journal of Sociology* 102:543–62.
Dunlap, Riley. 2010. "The Maturation and Diversification of Environmental Sociology: From Constructivism and Realism to Agnosticism and Pragmatism." Pp. 15–32 in *International Handbook of Environmental Sociology*, edited by M. Redclift and G. Woodgate. Cheltenham: Elgar.
Dunlap, Riley, and William Catton. 1979. "Environmental Sociology." *Annual Review of Sociology* 5:243–73.
Dunlap, Riley, and Richard York. 2008. "The Globalization of Environmental Concern and the Limits of the Postmaterialist Values Explanation: Evidence from Four Multinational Surveys." *Sociological Quarterly* 49:529–63.
European Commission. 2005. *Policy Review on Decoupling: Development of Indicators to Assess Decoupling of Economic Development and Environmental Pressure in the EU-25 and AC-3 Countries*. Brussels: European Commission.
Fedorov, Valery, Peter Hackl, and Werner Muller. 1993. "Moving Local Regression: The Weight Function." *Journal of Nonparametric Statistics* 2:355–68.
Firebaugh, Glenn. 1992. "Growth Effects of Foreign and Domestic Investment." *American Journal of Sociology* 98:105–30.
———. 2008. *Seven Rules for Social Research*. Princeton, N.J.: Princeton University Press.

Firebaugh, Glenn, and Frank Beck. 1994. "Does Economic Growth Benefit the Masses? Growth, Dependence, and Welfare in the Third World." *American Sociological Review* 59:631–53.

Fisher, Dana, and William Freudenburg. 2004. "Post-industrialization and Environmental Quality: An Empirical Analysis of the Environmental State." *Social Forces* 83:157–88.

Foster, John Bellamy. 2002. *Ecology against Capitalism*. New York: Monthly Review Press.

Foster, John Bellamy, Brett Clark, and Richard York. 2010. *The Ecological Rift*. New York: Monthly Review Press.

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.

Giddens, Anthony. 2009. *The Politics of Climate Change*. Cambridge: Polity.

Gilpin, Robert. 2001. *Global Political Economy*. Princeton, N.J.: Princeton University Press.

Givens, Jennifer, and Andrew Jorgenson. 2011. "The Effects of Affluence, Economic Development, and Environmental Degradation on Environmental Concern: A Multilevel Analysis." *Organization and Environment* 24:74–91.

Gould, Kenneth, David Pellow, and Allan Schnaiberg. 2004. "Interrogating the Treadmill of Production: Everything You Wanted to Know about the Treadmill but Were Afraid to Ask." *Organization and Environment* 17 (3): 296–316.

———. 2008. *The Treadmill of Production: Injustice and Unsustainability in the Global Economy*. Boulder, Colo.: Paradigm.

Gould, Kenneth, Allan Schnaiberg, and Adam Weinberg. 1996. *Local Environmental Struggles: Citizen Activism in the Treadmill of Production.* Cambridge: Cambridge University Press.

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 Modernisation and the Policy Process*. New York: Oxford University Press.

Hamilton, Lawrence. 1992. *Regression with Graphics*. Belmont, Calif.: Duxbury.

Hansen, James, Makiko Sato, Pushker Kharecha, David Beerling, Robert Berner, Valerie Masson-Delmotte, Mark Pagani, Maureen Raymo, Dana Royer, and James Zachos. 2008. "Target Atmospheric CO_2: Where Should Humanity Aim?" *Open Atmospheric Science Journal* 2:217–31.

Harper, Charles. 2004. *Environment and Society*. Upper Saddle River, N.J.: Prentice Hall.

Harvey, David. 2006. *Spaces of Global Capitalism*. London: Verso.

Hsiao, Cheng. 2003. *Analysis of Panel Data*. New York: Cambridge University Press.

Huber, Joseph. 2009. "Upstreaming Environmental Action." Pp. 334–55 in *The Ecological Modernisation Reader*, edited by Arthur Mol, Gert Spaargaren, and David Sonnenfeld. London: Routledge.

Inglehart, Ronald. 1990. *Culture Shift in Advanced Industrial Society*. Princeton, N.J.: Princeton University Press.

———. 1997. *Modernization and Postmodernization: Cultural, Economic, and Political Change in 43 Societies*. Princeton, N.J.: Princeton University Press.

Inglehart, Ronald, and Wayne Baker. 2000. "Modernization, Cultural Change, and the Persistence of Traditional Values." *American Sociological Review* 65:19–51.

IPCC (Intergovernmental Panel on Climate Change). 2007*a*. *Climate Change 2007: Mitigation of Climate Change*. http://www.ipcc.ch.

———. 2007*b*. *Climate Change 2007: The Physical Science Basis*. Cambridge: Cambridge University Press.

Jevons, William Stanley. (1865) 1906. *The Coal Question: An Inquiry Concerning the*

Progress of the Nation and the Probable Exhaustion of Our Coal-Mines, edited by A. W. Flux. London: Macmillan.
Jorgenson, Andrew. 2006. "Global Warming and the Neglected Greenhouse Gas: A Cross-National Study of Methane Emissions Intensity, 1995." *Social Forces* 84:1777–96.
———. 2009. "The Transnational Organization of Production, the Scale of Degradation, and Ecoefficiency: A Study of Carbon Dioxide Emissions in Less-Developed Countries." *Human Ecology Review* 16:64–74.
———. 2011. "Carbon Dioxide Emissions in Central and Eastern European Nations, 1992–2005: A Test of Ecologically Unequal Exchange Theory." *Human Ecology Review* 18:105–14.
———. 2012. "The Sociology of Ecologically Unequal Exchange and Carbon Dioxide Emissions, 1960–2005." *Social Science Research* 41 (2): 242–52.
Jorgenson, Andrew, and Ryan Birkholz. 2010. "Assessing the Causes of Anthropogenic Methane Emissions in Comparative Perspective, 1990–2005." *Ecological Economics* 69:2634–43.
Jorgenson, Andrew, and Brett Clark. 2009. "The Economy, Military, and Ecologically Unequal Relationships in Comparative Perspective: A Panel Study of the Ecological Footprints of Nations, 1975–2000." *Social Problems* 56:621–46.
———. 2010. "Assessing the Temporal Stability of the Population/Environment Relationship in Comparative Perspective." *Population and Environment* 32:27–41.
———. 2011. "Societies Consuming Nature: A Panel Study of the Ecological Footprints of Nations, 1960–2003." *Social Science Research* 40:226–44.
Jorgenson, Andrew, Christopher Dick, and Matthew Mahutga. 2007. "Foreign Investment Dependence and the Environment: An Ecostructural Approach." *Social Problems* 54:371–94.
Jorgenson, Andrew, and Kennon Kuykendall. 2008. "Globalization, Foreign Investment Dependence, and Agriculture Production: A Cross-National Study of Pesticide and Fertilizer Use Intensity in Less-Developed Countries, 1990–2000." *Social Forces* 87: 1–34.
Jorgenson, Andrew, James Rice, and Brett Clark. 2010. "Cities, Slums, and Energy Consumption in Less-Developed Countries, 1990–2005." *Organization and Environment* 23:189–204.
Kennedy, Peter. 2008. *A Guide to Econometrics*, 6th ed. Malden, Mass.: Blackwell.
Kentor, Jeffrey, and Terry Boswell. 2003. "Foreign Capital Dependence and Development: A New Direction." *American Sociological Review* 68:301–13.
Kolbert, Elizabeth. 2006. *Field Notes from a Catastrophe: Man, Nature, and Climate Change.* New York: Bloomsbury.
Lankao, P., D. Nychka, and J. L. Tribbia. 2008. "Development and Greenhouse Gas Emissions Deviate from the 'Modernization' Theory and 'Convergence' Hypothesis." *Climate Research* 38:17–29.
Leonard, Jeffrey. 1988. *Pollution and the Struggle for the World Product.* Cambridge, Mass.: Harvard University Press.
Longhofer, Wesley, and Evan Schofer. 2010. "National and Global Origins of Environmental Association." *American Sociological Review* 75:505–33.
Mahutga, Matthew, and David Smith. 2011. "Globalization, the Structure of the World Economy and Economic Development." *Social Science Research* 40:257–72.
McMichael, Philip. 2008. *Development and Social Change: A Global Perspective*. Thousand Oaks, Calif.: Pine Forge Press.
Mol, Arthur. 1995. *The Refinement of Production: Ecological Modernization Theory and the Chemical Industry*. Utrecht: Van Arkel.
———. 1997. "Ecological Modernization: Industrial Transformations and Environmental Reform." Pp. 138–49 in *The International Handbook of Environmental So-*

ciology, edited by Michael Redclift and Graham Woodgate. Northampton, Mass.: Elgar.

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

———. 2002. "Ecological Modernization and the Global Economy." *Global Environmental Politics* 2 (2): 92–115.

Mol, Arthur, Gert Spaargaren, and David Sonnenfeld. 2009. "Ecological Modernisation: Three Decades of Policy, Practice and Theoretical Reflection." Pp. 3–14 in *The Ecological Modernisation Reader*, edited by Arthur Mol, Gert Spaargaren, and David Sonnenfeld. London: Routledge.

Molotch, Harvey. 1976. "The City as a Growth Machine: Toward a Political Economy of Place." *American Journal of Sociology* 82 (2): 309–32.

OECD (Organisation for Economic Co-operation and Development). 2002. *Indicators to Measure Decoupling of Environmental Pressure from Economic Growth*. Paris: OECD.

Pellow, David. 2007. *Resisting Global Toxins: Transnational Movements for Environmental Justice*. Cambridge, Mass.: MIT Press.

Perkins, Richard, and Eric Neumayer. 2009. "Transnational Linkages and the Spillover of Environment-Efficiency into Developing Countries." *Global Environmental Change* 19:375–83.

Polimeni, John, Kozo Mayumi, Mario Giampietro, and Blake Alcott. 2008. *The Jevons Paradox and the Myth of Resource Efficiency Improvements*. London: Earthscan.

Rice, James. 2007. "Ecological Unequal Exchange: International Trade and Uneven Utilization of Environmental Space in the World System." *Social Forces* 85:1369–92.

Roberts, Timmons, Peter Grimes, and Jodie Manale. 2003. "Social Roots of Global Environmental Change: A World-Systems Analysis of Carbon Dioxide Emissions." *Journal of World-Systems Research* 9:277–315.

Roberts, Timmons, and Bradley Parks. 2007. *A Climate of Injustice: Global Inequality, North-South Politics, and Climate Policy.* Cambridge, Mass.: MIT Press.

Robinson, William. 2004. *A Theory of Global Capitalism*. Baltimore: Johns Hopkins University Press.

Rosa, Eugene, Andreas Diekmann, Thomas Dietz, and Carlos Jaeger, eds. 2010. *Human Footprints on the Global Environment: Threats to Sustainability.* Cambridge, Mass.: MIT Press.

Rosa, Eugene, Richard York, and Tom Dietz. 2004. "Tracking the Anthropogenic Drivers of Ecological Impacts." *Ambio* 33 (8): 509–12.

Sanderson, Stephen. 1999. *Macrosociology*. New York: Longman.

Schnaiberg, Allan. 1980. *The Environment: From Surplus to Scarcity*. New York: Oxford University Press.

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

Schofer, Evan, and Ann Hironaka. 2005. "The Effects of World Society on Environmental Outcomes." *Social Forces* 84:25–47.

Schofer, Evan, and John Meyer. 2005. "The Worldwide Expansion of Higher Education in the Twentieth Century." *American Sociological Review* 70:898–920.

Schwom, Rachael. 2009. "Strengthening Sociological Perspectives on Organizations and the Environment." *Organization and Environment* 22:271–92.

Sen, Amartya. 1999. *Development as Freedom*. New York: Anchor.

Shandra, John, Bruce London, Owen Whooley, and John Williamson. 2004. "International Nongovernmental Organizations and Carbon Dioxide Emissions in the Developing World: A Quantitative, Cross-National Analysis." *Sociological Inquiry* 74:520–44.

Smith, Jackie, and Dawn Wiest. 2005. "The Uneven Geography of Global Civil Society:

National and Global Influences on Transnational Association." *Social Forces* 84: 632–52.
Sonnenfeld, David. 1998. "From Brown to Green? Late Industrialization, Social Conflict, and the Adoption of Environmental Technologies in Thailand's Pulp Industry." *Organization and Environment* 11:59–87.
Sonnenfeld, David, and Michael T. Rock. 2009. "Ecological Modernisation in Asian and Other Emerging Economies." Pp. 359–71 in *The Ecological Modernisation Reader*, edited by Arthur Mol, Gert Spaargaren, and David Sonnenfeld. London: Routledge.
Spaargaren, Gert. 1997. "The Ecological Modernization of Production and Consumption: Essays in Environmental Sociology." Dissertation. Wageningen University, Department of Environmental Sociology.
———. 2009. "Sustainable Consumption: A Theoretical and Environmental Policy Perspective." Pp. 318–33 in *The Ecological Modernisation Reader*, edited by Arthur Mol, Gert Spaargaren, and David Sonnenfeld. London: Routledge.
Spaargaren, Gert, and Maurie Cohen. 2009. "Greening Lifecycles and Lifestyles: Sociotechnical Innovations in Consumption and Production as Core Concerns of Ecological Modernisation Theory." Pp. 257–74 in *The Ecological Modernisation Reader*, edited by Arthur Mol, Gert Spaargaren, and David Sonnenfeld. London: Routledge.
Stern, Nicolas. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press.
Stretesky, Paul, and Michael Lynch. 2009. "A Cross-National Study of the Association between Per Capita Carbon Dioxide Emissions and Exports to the United States." *Social Science Research* 38:239–50.
U.S. National Research Council. 2010. *Advancing the Science of Climate Change*. Washington, D.C.: National Academies Press.
Wagner, Martin. 2008. "The Carbon Kuznets Curve: A Cloudy Picture Emitted by Bad Econometrics?" *Resource and Energy Economics* 30:388–408.
White House. 2002. "Global Climate Change Policy Book: Executive Summary." http://georgewbush-whitehouse.archives.gov/news/releases/2002/02/climatechange.html.
Wooldridge, Jeffrey. 2005. *Introductory Econometrics: A Modern Approach*, 3d ed. Mason, Ohio: Thomson.
World Bank. 2007. *World Development Indicators*. CD ROM version. Washington, D.C.: World Bank.
WRI (World Resources Institute). 2007. *Earth Trends Data CD-ROM*. Washington, D.C.: World Resources Institute.
York, Richard. 2006. "Ecological Paradoxes: William Stanley Jevons and the Paperless Office." *Human Ecology Review* 13:143–47.
———. 2007. "Demographic Trends and Energy Consumption in European Union Nations, 1960–2025." *Social Science Research* 36:855–72.
———. 2008. "De-carbonization in Former Soviet Republics, 1992–2000: The Ecological Consequences of De-modernization." *Social Problems* 55:370–90.
York, Richard, and Eugene Rosa. 2003. "Key Challenges to Ecological Modernization Theory: Institutional Efficacy, Case Study Evidence, Units of Analysis, and the Pace of Eco-efficiency." *Organization and Environment* 16:273–88.
York, Richard, Eugene Rosa, and Thomas Dietz. 2003. "Footprints on the Earth: The Environmental Consequences of Modernity." *American Sociological Review* 68:279–300.
———. 2009. "A Tale of Contrasting Trends: Three Measures of the Ecological Footprint in China, India, Japan, and the United States, 1961–2003." *Journal of World-Systems Research* 15:134–46.
Zhou, Min. 2010. "Multidimensionality and Gravity in Global Trade, 1950–2000." *Social Forces* 88:1619–44.