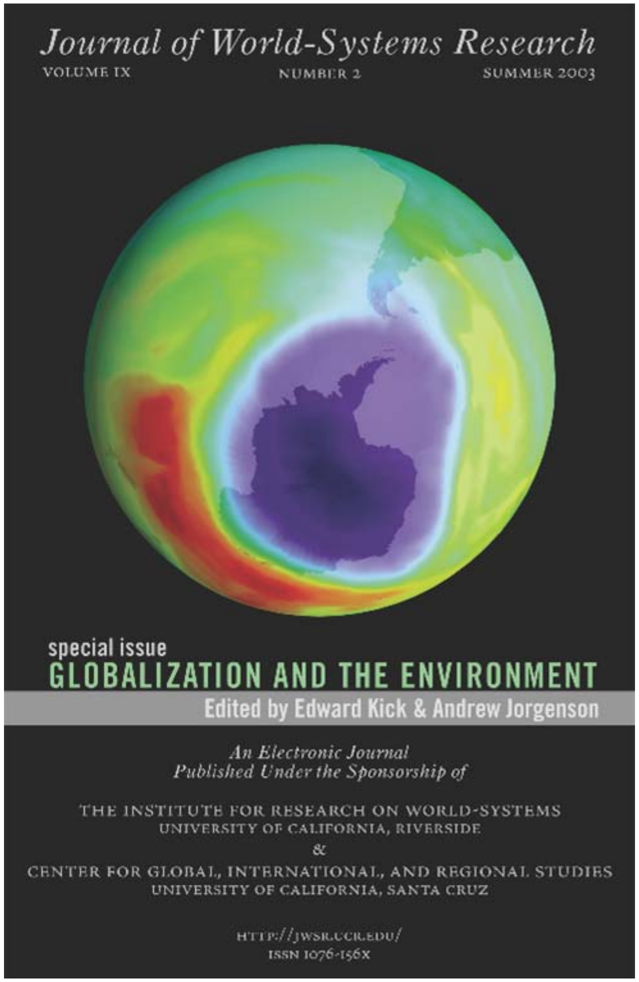

ABSTRACT

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

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

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INTRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

5. White House. 2002b.

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

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

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

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

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

7. Roberts 2001.

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

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

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

WORLD-SYSTEMS THEORY AND THE GLOBAL ENVIRONMENT

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

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

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

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

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

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

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

CORE PRODUCTION AND CO_2 FROM FOSSIL FUELS

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

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

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

Energy use is high in the core because of the substitution of fossil fuels and other inorganic energy sources for human and animal power. Energy consumption is closely correlated with the size of a country's economy, and kilowatt hours of electricity consumed has often been used as a proxy for Gross National Product (e.g.Cook 1971; Humphrey and Buttel 1982: 154-8; Bollen and Appold 1993). At the same time, however, their advanced infrastructure—transportation, communications and production systems—makes it possible for both the social and physical machineries of production to be more thermodynamically efficient. This phenomenon is now discussed in terms of ecological modernization (Simonis 1989; Spaargaren and Mol 1992; Mol and Sonnenfeld 2000; Mol 2001). We expect that such efficiency has developed largely as the result of firm-level decisions to increase per-worker productivity, combined with government-level decisions to facilitate that production with improved infrastructure. Because efficiency gains are inevitably limited and the production of new efficient machines

itself requires energy and materials, we do not believe that capital can entirely replace energy in this relationship.[9]

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

NON-CORE PRODUCTION AND CO_2 FROM FOSSIL FUELS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ISSUES OF DATA AND MODEL SPECIFICATION

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

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

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

SUMMARY TABLE OF HYPOTHESES

Major Conceptual Hypotheses:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CO_2 INTENSITY AND GLOBAL STRATIFICATION

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

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

Figure 1 – Carbon Dioxide Emissions in the World System

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

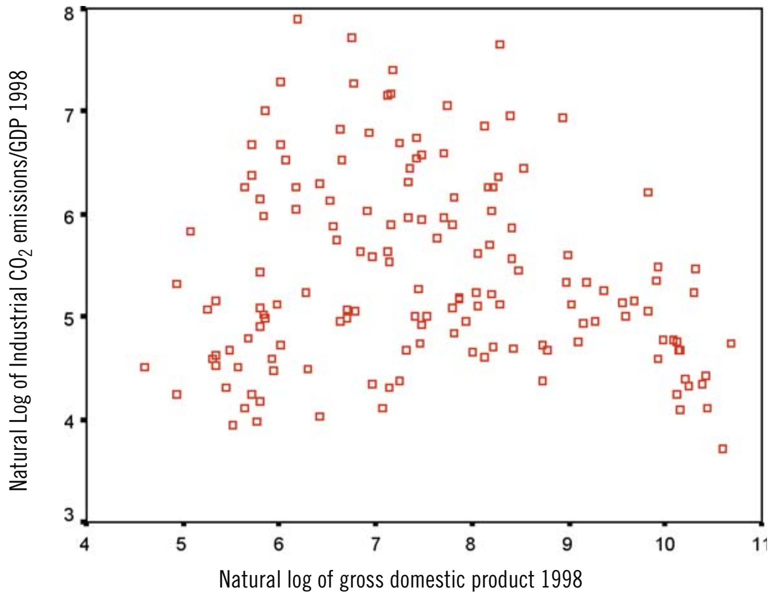
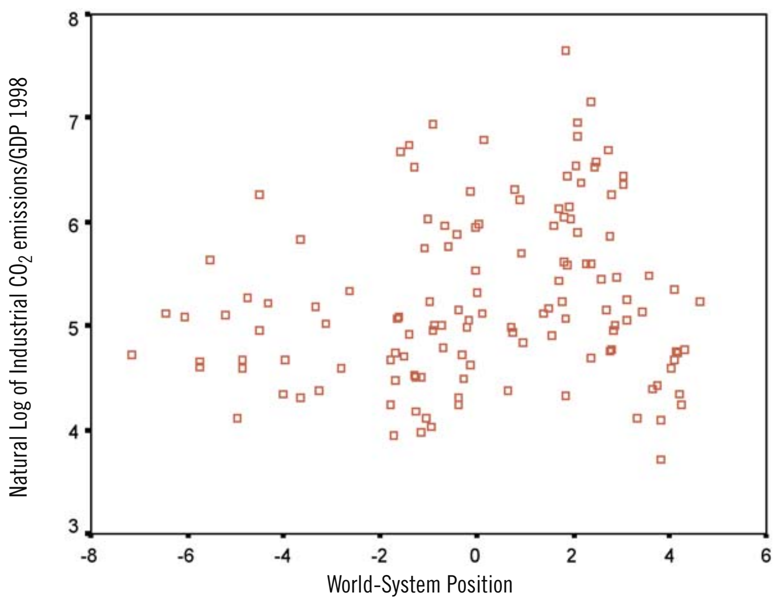


Figure 1b: Natural log of national carbon emissions intensity (CO_2 emissions per unit of GDP), 1988, vs. hybrid Terlouw index of position in the world system.



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

MODELING SOCIAL FACTORS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Meanwhile our indicator of economic growth (GDP growth rate between 1980 and 1989) was seen to have a moderately *negative* association with carbon intensity (contrary to our prediction). This suggests that the fastest growing economies throughout the eighties were those investing in industries that generate relatively lower levels of CO_2 per unit of economic activity generated. Examples of such investments might be tourism, banking and light assembly, with slower growth in countries dominated by older heavy industries (e.g. Eastern Europe, the core).[22] Said the other way around then, these findings suggest that countries which are reducing their CO_2 intensity appear to be also those which experienced the strongest economic growth in the 1980s. We found in a similar analysis that there is a connection between national debt and carbon emissions intensity from deforestation (Grimes, Roberts and Manale, n.d.). The important question of patterns in rates of *change* in carbon intensity must await future research.[23]

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

SUMMARY AND CONCLUSION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

LN(Industrial CO_2 emissions/GDP) [LNICO$_2$GD]: Natural log of metric tons of CO_2 emissions from fossil fuel use, cement manufacture, and gas flaring, per unit of GDP, 1989 (CO_2: CDIAC 1991; Marland and Rotty 1984; GDP: World Bank 1992c; WRI 1992).

LN(Total CO_2 emissions/GDP)[LNCO$_2$GDP]: Natural log of sum of Industrial and Deforestation CO_2 emssions/GDP. See above for sources.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DESCRIPTIVE STATISTICS FOR 1998 ANALYSIS

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

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