Population versus Consumption:
Determining the Real Driving Force of Environmental Degradation

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Précis

This work addresses the question of the driving forces of resource degradation, specifically population and consumption patterns. Based on recent studies by the United Nations and the World Wildlife Fund, it is apparent that the value of services provided by nature is in decline. In order to adequately address the problem and insure that the global ecosystem continues to supply humanity with the raw materials, services, and aesthetic values it needs, the cause must be discovered. While economists and environmentalists have a multitude of tools and information at their disposal, there is still no agreement on the source of the degradation.

In purely economic terms, the issue of resource degradation and decline is of paramount importance. Without the materials and services provided by the natural environment, there would be no production, consumption, trade, or even markets. Every good found within an economic system comes from the natural environment rather directly or indirectly. Should that environment become degraded beyond the extent that technology can repair, the world economy and certainly all living beings will face certain devastation. Environmentally, resource decline and destruction will have detrimental effects on every living creature and system in the world. The symptoms can already be seen today in the prevalence of water and food shortages, global warming, rapid extinction rates, and the decline in biodiversity. A solution must be found.

To fully investigate the main drivers of resource degradation, this paper uses empirical econometric regression analysis as well as an in-depth analysis of current environmental databases, evidence, and research. Combined, the two methods should produce a clear assessment of the current ecological state as well as the main determinants in its health. Of course any project delving into global processes and systems cannot possibly encompass or include every variable, but this paper utilizes all current information and accepted economic analysis available. Creating models to describe present states and supplementing those with current findings, this paper used all available resources to develop a concise study of the issue. Through the course of investigation, however, the analyses provided ambiguous and often counterintuitive results.

The results did not strongly indicate population or consumption as a main driver. This is consistent with the bulk of available research into the issue. Trends appear that suggest consumption may be at the heart of change, but no definitive evidence has been produced. In this paper, it was found that the two variables, consumption and population, could not be physically or empirically disaggregated, meaning that their individual effects could not be explicitly determined. This fact is perhaps the key to understanding why policy prescriptions in regard to natural resources are often misguided and ineffective. If one cannot define the root of a problem, it cannot efficiently be addressed and solved.

The results do not necessarily mean that there is no solution to the problem of identifying whether population numbers or consumption patterns are responsible for environmental decline. The results indicate that more advanced models are needed, models that can incorporate non-economic values (such as biological importance, system stability, and aesthetic or spiritual value) and intrinsic worth of the natural system. How this is to be achieved is beyond the scope of this paper, but it is quite possible that with time and further research, new models that are capable of including both economic and non-economic variables will be created and can better address this multifaceted issue.

Table of Contents

Figures and Tables

Introduction

Since the birth of the environmental movement in the 1960's and 1970's, the question of the driving forces in environmental damage has been debated and contemplated by scientists, environmentalists, politicians, economists, and the general public with no distinct or clear culprit to be found. Paul Ehrlich's 1968 book, *The Population Bomb*, deemed population as the ultimate environmental enemy, drawing on the Malthusian catastrophe theory wherein population was predicted to grow exponentially until a certain capacity level, after which human populations crashed due to famine, disease, and overextension of earth's resources. Of course, Ehrlich's predictions (like those of Malthus), were incorrect, and humanity took a drastically different path wherein the world's food production grew exponentially larger than its population and more individuals now enjoy a higher quality of life.

From its humble beginnings, the environmental movement has grown and changed and the debate has turned away from population per se to the roles of affluence, poverty, consumption, and patterns of economic development as the main drivers ecosystem change. No longer is the fear of a population crash looming, but rather an "earth crash" looms over us. The United Nations 2005 *Millennium Ecosystem Assessment Report* provides a detailed, objective look at the status of the world's ecosystem as well as projections for the functioning thereof into the future. The report states that many of our natural resource stocks (especially fossil fuels, fisheries, rainforests, and freshwater) will face drastic reductions and/or complete collapse if we continue the extraction and use patterns of the last several decades. Not only is this a frightening assessment of natural ecosystems, but it means certain disaster for the global economy and continued development. Without biodiversity and the services provided by the environment, the entire concept of development beyond subsistence will be impossible (WWF 2005, Rao 2000).

For ecologists, the basic idea of the world as a closed, finite system is integral to the argument. We have only one planet and one resource stock, leaving humanity and the rest of the ecological world with nothing once it has been depleted. Of course artificial and manufactured products, materials, and substitutes are available, but those too must be made from something. In fact, *everything* that humans produce and consume comes from the biosphere. Each and every aspect of human life is dependent, whether directly or indirectly, on the bounty of the earth. Once caches have been exhausted, sinks have been filled, or sources have been degraded beyond use, there are no other options (Suzuki 2002, Rao 2000, Sessions 1985).

Economists can generally be found on the other side of the issue: that there is no resource shortage and moreover, economic growth and development can and must continue indefinitely to ensure that no such problems develop. William Poole, president of the Federal Reserve Bank of St. Louis, said in a 2005 lecture that deficit spending and consuming beyond a nation’s net capital means is not only good but essential for robust economic performance and growth. Hollander (2003) maintains that affluence and increased spending and consumption are the keys to solving the environmental crises faced today (because with affluence comes the ability to live beyond subsistence and therefore the ability to devote more time and energy to environmental concern and improvement). Population can continue to grow as large as we allow it to without fear, so long as more of the world becomes economically developed and more consumers and producers are added to the market. Any environmental supply issue will effectively be dealt with and solved with technological advance, development, and increased affluence. Prices will necessarily increase to accommodate for falling supply. Hence, environmental services will become a luxury good available to the affluent at a high price, which will give incentive to producers to develop alternatives so that all consumers can continue to participate in the market (Hall and Lieberman 2005).

Further, economists counter that if shortages of resources *do* occur that cannot be compensated for by technology, the market will send signals that will allow us to price and utilize remaining stores accordingly. Prices are said to be indicative of current supply and demand and when supply falls or demand increases, prices will necessarily increase to accommodate for the changes and allow for goods and services to be distributed appropriately. Unfortunately, in the natural resource market (not to mention many other markets), price is not an indubitable indicator of real conditions (many natural resource stock amounts are estimates at best). Often prices do not include external costs that may be very damaging to the environment but go unaccounted for. Nevertheless, economic theory maintains that prices and markets will act to safeguard us against imminent environmental collapse (Hall and Lieberman 2005).

Thus, the argument continues. Economists push forward with empirical evidence and models that offer inconclusive results and environmentalists continue to produce physical evidence of degradation, but with no concrete proof that population or consumption patterns are to blame. While both methods of investigation are sound, there is an inherent shortfall when addressing the population/consumption question. This paper will attempt to identify this shortfall by conducting empirical investigation as well as consideration of current environmental knowledge.

Background and Methodology

The United Nations *Millennium Ecosystem Assessment* published in 2005 is the most comprehensive global ecosystem analysis ever. In detail, it investigates the impacts humans have had on the natural environment and its services. According to the report, "human activity is putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted," (UN 2005). Essentially, human demands and consumption are placing dangerous pressure on natural systems, pressure that will lead to eventual collapse. The source of this pressure must be identified in order to take appropriate action and it appears that over-using scarce resources is to blame. The *Assessment* identifies "the failure to value ecosystems" as a major contributor to this problem, and proposes an overhaul of the economic theory that goes into decision making to take into account the full value of the services provided by the ecosystem (Department of Economic and Social Affairs 2005). For all intents and purposes, the report's authors conclude that the basis for policy making is flawed economics based on improper pricing and market mechanisms.

The *Millennium Ecosystem Assessment* is the paramount body of evidence and information pertaining to the state of the natural environment. Carried out from 2001 through 2005, the *Assessment* considers "the consequences of ecosystem change for human well-being and [establishes] the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being," (UN 2005). The body of the work consists of current scientific research, models, databases, as well as information held by the private sector, indigenous peoples, individuals, and special interest organizations (UN 2005). While it does not necessarily produce new information, the *Assessment* creates a comprehensive picture of the world ecosystem and its services and offers "the judgment of experts to existing knowledge to provide scientifically credible answers to policy-relevant questions," (UN 2005). This makes it an indispensable tool in any investigation into human impacts on the natural system and natural resource consumption.

With all this in mind, a further discussion of natural resource scarcity (and its effects on price) as viewed by most economists is warranted. Price theory dictates that prices will necessarily increase when resources become scarce and decrease when resources are abundant (Pindyk et al. 2005). Prices will also increase as demand increases or supply decreases or will conversely fall when demand falls or supply increases. In terms of natural resources, prices are based on the ability to extract the resource, the value of the resource to the market, amount of capital and labor required, and estimated supply. Technology, more so than in any other industry, plays a huge roll in natural resource pricing. The more of the resource that is extracted, the more difficult it becomes to extract it as easily accessed supplies are depleted and more remote supplies must be located. Technological advance, if it keeps pace with or outpaces extraction, can serve to keep prices of resources stable, or perhaps lower than they have been in the past (Brown & Wolk 2000). Additionally, expectations of higher prices motivate individuals to find or invent new technology that will offset those price increases, therefore making the very mechanism that signals increasing scarcity actually stimulate the changes necessary to avoid price increase (Brown & Wolk 2000).

Moreover, the Hotelling rule describes the condition wherein current and expected future prices of resources determine current prices simultaneously. The information and technology available now determine our expectations of future prices and therefore our actions (Hotelling 1931). And the Malthusian population theory, while historically disproved, has been a starting point for several other ecological and environmental theories regarding impacts and system capacities. Ehrlich continued research into the impacts that population plays on the planet, and introduced the IPAT identity with John Holdren in 1972. The IPAT identity (environmental Impact= Population x Affluence x Technology (impact per unit of production or consumption)) is a well-recognized tool when investigating the effects of human activities on the environment. According to York et al. (2003, 2005), the IPAT's main strengths are that it clearly delineates the impacting factors and allows for analysis of the impacts of single factors. Further, Chertow (2001) discusses the great simplification it provides in studying anthropogenic environmental factors. Indeed many scholars have used it as a starting point for evaluating interactions among population, consumption, and technological change (see Gans and Jost 2005, Lantz and Fang 2005, Wetzel and Wetzel 1995, Shi 2002) as well as intergovernmental bodies such as the United Nations, nongovernmental organizations including the World Wildlife Fund, and numerous other groups, researchers, and clearinghouses.

Despite its ability to simplify and encompass diverse factors, the IPAT identity is not adequate to fully investigate and empirically examine the environmental and economic problems arising from resource use. As an identity, IPAT does not allow for regression analysis or hypothesis testing as the equation must always equal, resulting in an R^2 value of 1.0. Several economists have developed alternative models to allow for regression analysis and hypothesis testing, such as the ImPACT (impact in CO_2 emissions= population x per capita GDP x energy consumption per unit GDP x CO_2 emissions per unit of energy consumption) model and the STIRPAT analysis (York et al. 2003). The STIRPAT analysis is the most complete model thus far and deserves further discussion.

The main difference between the STIRPAT model and that of IPAT and ImPACT models is that it includes a stochastic error term which allows for regression analysis. The specification of STIRPAT is:

$$I_i = aP^b{}_iA^c{}_iT^d{}_ie_i$$

where the constant (a) serves to scale the model, (b), (c), and (d) are the exponents of Population (P), Affluence (A), and Technology (T), and e is the error term (York et al. 2003). The STIRPAT model can be formulated to include supplementary variables that are normally consolidated into the T variable. Ecological elasticity (EE) is a quantitative figure that can be included within the model and allows us to understand and disaggregate a proportional change in environmental impacts due to a change in any of the driving forces included in the analysis (York et al. 2003, 2005). Ecological elasticity then works in the same manner as price or income elasticity:

$$\log I = \log A + b(\log X) + e$$

where for every 1% change in the driving force in focus, there is a certain % change in the response variable (log I).

T can further be disaggregated into any number of additional factors, as long as they are consistent with and appropriate within a regression analysis model (for example, no multiplicative specifications). In the same manner, P and A can also be disaggregated into many different categories as well (York et al. 2003).

Dummy variables can also be included, which have been found to be highly useful in analysis of environmental impacts (York et al. 2003 and 2005, WWF 2002, Harbaugh et al. 2002, Hilton 1998, Shi 2002). Climate or latitude in particular is an incredibly important part of impact analysis. According to the work of York et al. (2003), tropical nations have only 51% of the CO_2 emissions of non-tropical nations. This is a significant figure and will thus be considered in this paper. Also, dummy variables for political climate (democratic vs. non-democratic) have been found to be significant variables in impact analysis by Harbaugh et al. (2002). Further, different periods of time and specific years can be included as dummy variables to account for any extraordinary differences, as can income levels above and below certain points (to investigate impacts in impoverished nations versus affluent nations, for example.

Ecological footprint (EF) is another widely recognized measure and indicator of human impacts on the natural environment. By definition, the EF of a country is “the amount of land area that would be required to produce the resources it consumes and to absorb the wastes it generates,” (York et al. 2005, WWF 2006). The development of EF figures is based on the regenerative capacity of ecosystems, consumption patterns, production byproducts, and waste intensity. Consumption in this instance is calculated by adding imports and subtracting exports from production (York et al. 2005, Wackernagel et al. 1999). EF calculations also include a weighting system that accounts for differences in productivity relative to the average worldwide productivity (York et al. 2005).

Much research has been done to further discover the interactions between the environment and affluence and consumption using the Environmental Kuznets Curve (EKC) model. This model is based on the theory that there is an inverted U-shaped relationship between affluence and pollution generation, meaning that as nations develop and prosper, their environmental impact decreases. The basic theory underlying this model is that economic development, consumption and an increase in per capita income is necessary to improve the state of the environment. Grossman and Krueger in their 1995 paper specified the equation and found that the turning point or location of the crest of the U is at $8000 per capita. Their specification is as follows:

$$Y = G_{it}ß_1 + G^2_{it}ß_2 + G^3_{it}ß_3 + L_{it}ß_4 + L^2_{it}ß_5 + L^3_{it}ß_6 + X_{it}ß_7 + \mu_i + e$$

where G is per capita GDP at time t for a particular country in which the monitoring site i is located, L is the three year average of lagged per capita GDP, and X is a site specific variable.

Several researchers (Harbaugh et al. 2002, Levinson 1998, Gawande et al. 2001, Rao 2000, Hollander 2003) have found evidence of an EKC of several pollutants. This would indicate that poverty, not affluence is the main culprit in terms of environmental degradation, and further that population plays no discernible impact so long as incomes and development keep increasing in step. However, just as many researchers have found no evidence of existence of the EKC (Lantz and Feng 2005, Khanna and Plassmann 2004, Moomaw and Unruh 1997, Rothman 1998). These researchers have found that the turning point is located at different points for different pollutants and countries, and sometimes is found to be completely unrealistic and thus have no empirical value. Also, the EKC in many situations and nations has been found to be opposite of what has been expected, namely a U-shaped result. This would indicate that affluence, not poverty is a main driver of environmental damage.

Additionally, the EKC has been criticized for being spatially biased in that it only works in situations and areas where affluent individuals can get away from pollution. More specifically, affluence only seems to increase environmental quality when the pollutant is easily separated from the individual, as with nuclear waste sites, garbage dumps, or polluting industries. In the case of air pollution, or other degraded common resources, the EKC has not been seen to be correct in predicting economic and environmental changes (Rothman 1998, Lantz and Feng 2005). Because of these inconsistencies, the EKC will not be a major focus of this paper.

Having described the prior research on this topic, it is clear that the knowledge and information base is robust and will be adequate to formally test the hypothesis that consumption patterns (which are interdependent with affluence) are the main driving forces of environmental degradation. Alternatively, the hypothesis that population levels are responsible for the degradation of earth's resources will also be empirically tested. By integrating a number of different theories and variables, a stronger correlation between responses and variables should be seen.

Empirical Model & Data Description

The empirical model used will be a basic Ordinary Least Squares (OLS) regression form of the STIRPAT equation, focusing on affluence, population, and technological change in the form of several representative variables. In addition, EF will be integrated in the analysis to fully grasp the impact of humans (either through consumption of resources or population pressures). Time series data will be utilized to strengthen the results. Dummy variables will be included, as per the suggestion of York et al. (2005) that will account for differences in political climate and latitude.

Responses modeled will be CO_2 emissions per capita, SO_2 emissions per capita, annual percent change of deforestation, and energy consumption in kilowatt hours. These response variables show both air and land impacts and based on current research and available data, provide the most complete world observations of change.

CO_2 is measured using national averages which are computed by government or non-governmental environmental monitoring agencies. Testing equipment, facilities, and results are overseen by the United Nations or other inter-governmental and non-governmental agencies to ensure that each nation measures in the same way and at the same frequency. This ensures that the most accurate data and averages are gathered. SO_2 measurements are gathered similarly, with international standards and procedures (United Nations 2006).

The percent change of deforestation response variable is the annual change in forested land. This figure is the net deforestation rate, which takes into account deforestation rates as well as replanting and reclamation actions (Mongabay.com 2007).

Energy in kilowatt hours is the national reported kilowatt hour use as reported to the United Nations Development Programme, presented in the *Human Development Report* each year (2006).

Independent variables tested within each model will include population which will be further disaggregated into rural and urban population to determine if any relationship between locations of population centers exists. Affluence will be illustrated in the model by using GDP per capita figures (1995 $US) and constant GDP (1995 $US), final household consumption expenditure, final government consumption expenditure, gross national expenditure, and final expenditure, all from the World Bank Human Development Index (2004, 2006). These variables will demonstrate what, if any, impact consumption and population have on the response variables.

Technology will be modeled by using the variables of percent of GDP in manufacturing industries, vehicles per capita, and the dummy variable of compliance with or signatory to clean technology agreements and policies, as defined by the *Human Development Report* (2006). Technology in this model is also a catch-all for any other impacts and forces not specified in the model.

Finally, dummy variables will include those defining tropical versus non-tropical regions. Tropical is defined as any nation with a majority of land mass located between the Tropic of Cancer and the Tropic of Capricorn. Non-tropical regions comprise any nations lying outside of the tropical region or those nations with less than half of their land mass within the specified borders. The political climate dummy describes the democratization index of the nation. Based on data gathered and presented by *The Economist* (2007) in their yearly democracy index, nations were given a 1 if they were described as being in transition or were under autocratic rule. Nations described as “flawed” democracies were included as democratic nations. This dummy is included to determine whether political climate impacts the environmental and economic actions of a nation.

Dummies for ratification of international environmental treaties and existence/formation of nationwide, government sponsored environmental strategies and action plans were also included as an indicator of technology. It is assumed that nations that have ratified and/or have a government sponsored environmental action plan to combat degradation will be instituting technological and fundamental changes (World Bank 2006). Further descriptions of all variables can be found in Data Appendix A.

Results

Table 1: Regression analyses using different response variables	**1 CO_2 Emissions (metric tons/capita)**	**2 SO_2 Production (metric tons)**	**3 Deforest-ation (annual % change)**	**4 Electric power use (kWh)**
Constant	12.961	2763617	10.734	661
Environmental Strategies/action plans	-.4485	-8401	-2.2044	-441.4
Ratification of climate change treaties	-.8724	61094	.679	7.0
Tropical	-2.7425	-557196	-.529	-523.6
Non-democratic	.5732	-633212	.223	-333.3
GDP per capita	.00016292	23.09	-.00007681	.25849
Government final consumption	.00167	27737	.03391	111.09
Household final consumption	-.11552	-19451	-.13846	-9.81
Total land area (sq km)	.00000039	-.1328	-.00000006	.0004043
Population, rural	-.00000001	-.001885	0	.00001004
Population, urban	-.000000000	.00611	0	-.00003145
R^2 (adjusted)	53.2%	4.6%	9.9%	65%
S	3.35475	2678115	5.18988	2505.46
Observations (cases) used	158	129	126	112
P	.000	.109	.014	.000

After running multiple regression models using data from years 1999-2004, each with an array of variables, results are less conclusive than hoped. Table 1 shows regression results using an array of response variables with different dependent variables.

The expected sign for the dummy variables environmental strategies/action plans and ratification of climate change treaties is negative, yet in models 2, 3, and 4, the sign is positive. This indicates that the ratification of climate change treaties increases SO_2 production by 61094 metric tons; increases deforested land area by .679 square kilometers; and increases electric power consumption by 7.0 kilowatt hours. This is counterintuitive.

Contrary to expectations, in models 2 and 4, having a non-democratic system of government actually decreased a nation's impact in response variable. The United Nations asserts in the *Millennium Ecosystem Assessment* that democratization is essential for combating environmental degradation and that nations with autocratic systems generally have a more detrimental and damaging impact. Again, these results are counterintuitive to what is known of political climate interactions with the environment.

Another variable that presented unexpected negative coefficients in all models was household final consumption. Defined as all purchases of and expenditures on goods and services by any non-government agencies and private persons, household final consumption is an indicator of demand for resources. Nevertheless, in all four models, it has a negative coefficient, meaning that for every increase in household consumption, environmental impacts will decrease by that amount. There is a strong negative correlation between household consumption and environmental impact. Table 2 and 3 illustrate this.

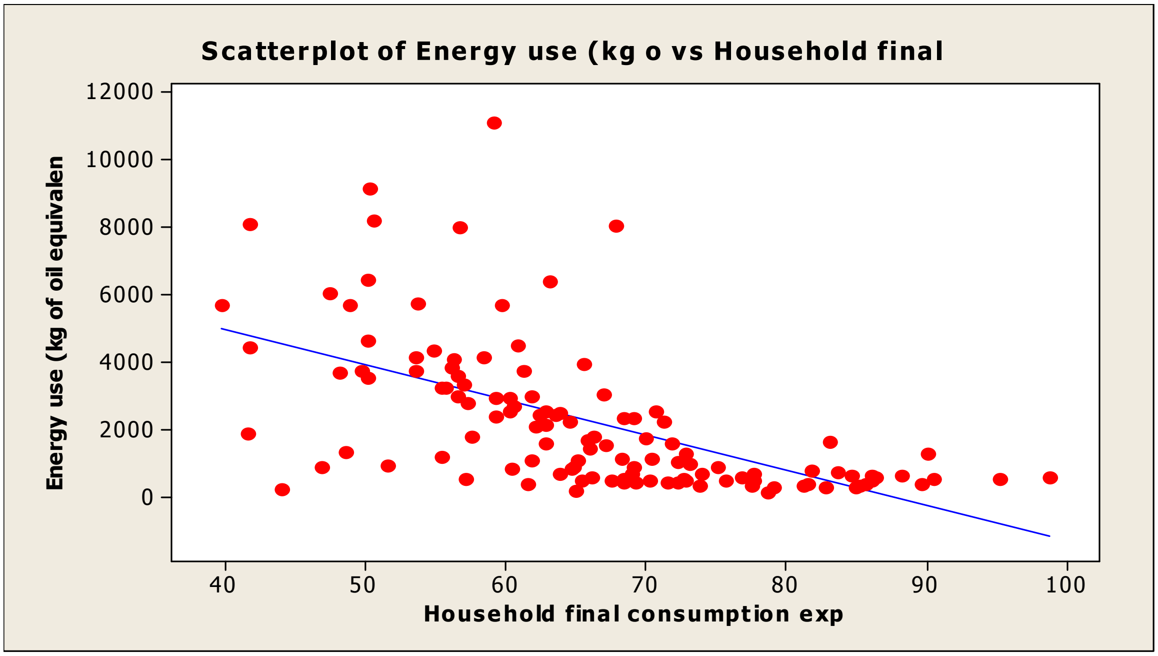


Table 2: Household final consumption versus energy use (kg of oil equivalent). This shows a clear negative correlation between consumption and energy use.

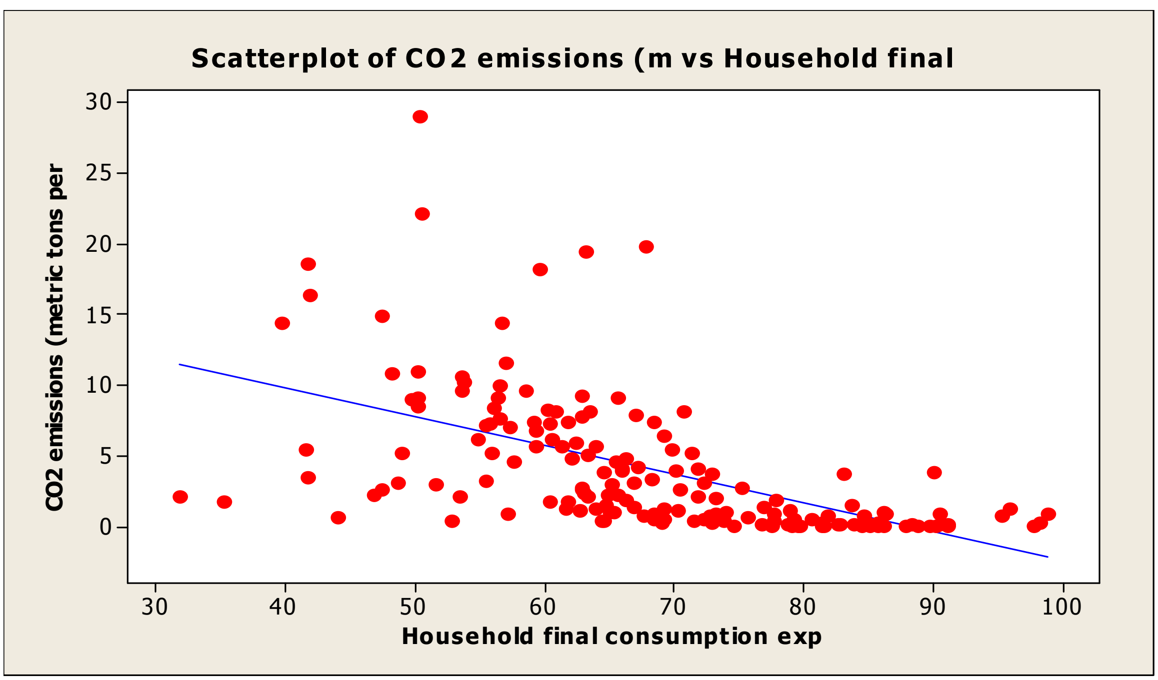


Table 3: Household final consumption versus CO_2 production (metric tons per capita). Again, a clear negative relationship is seen between CO_2 emissions and consumption

As expected, government final expenditure has a positive coefficient in all models, indicating that for every increase in government consumption, environmental impact increases by that amount.

Interestingly, population (disaggregated into rural and urban population) had very little, if any impact on the environmental responses. This would seem to indicate that population has virtually no bearing on resource depletion or environmental degradation. We therefore cannot consider it to be a main driver of environmental degradation, contrary to what Ehrlich (1972) and Malthus would predict.

Additionally, contrary to many economists and the EKC theory in particular, the GDP per capita coefficient in three of the four models is positive. This means that for every increase in GDP per capita, environmental impact increases. Deforestation rates, however, are inversely related, where an increase of $1 of GDP per capita decreases annual deforestation rates by .00007681 square kilometers. While this may be negligible for nations experiencing small GDP per capita gains, in nations experiencing high rates of development and growth, this figure is significant. For instance, if GDP per capita were to increase by $100, this would equate to a decrease in deforestation of .008 square kilometers, or 1.9768 acres. An increase of $1000 would result in a decrease in deforestation of nearly 20 acres.

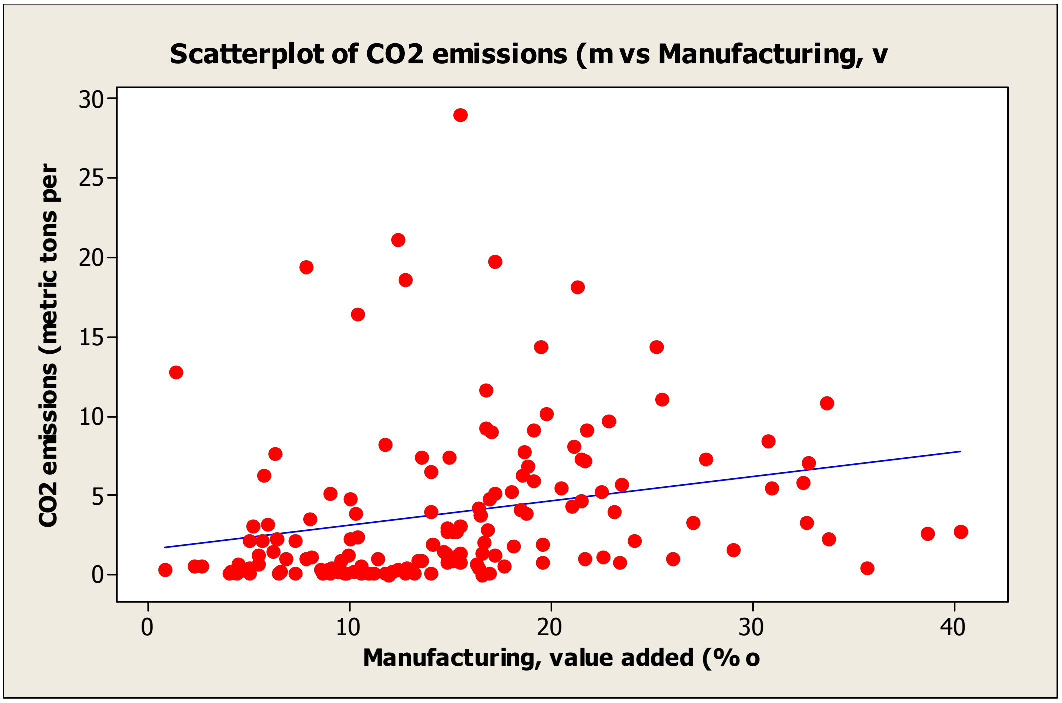
Table 4 presents the results of several other regressions using the same response variables, but with alternative explanatory variables. These models all use CO_2 as the dependent variable, with a number of different consumption-based explanatory variables. Again we see that in two of the three models that included it, household final consumption has a negative coefficient, indicating that for every increase in consumption, there is a decrease in CO_2 emitted. Further, as GDP per capita increases in models 5 and 8, the positive coefficient indicates that CO_2 emissions increase as well.

Table 4: **CO_2 emissions as dependent variable**	**5**	**6**	**7**	**8**
Constant	10.123	1.1890	10.832	13.343
GDP per capita		.00029082	.00021188	
Manufacturing (% of GDP)	.11328	.04557		.08942
Industry (% of GDP)	-.02501			-.05624
Current expenditure	-.000000000			
Total expenditure (% of GDP)	-.03123		-.02290	.07206
General gov't final consumption	.01332			-.10485
Gross national expenditure	-.03123			
Household final consumption	-.09345		.06584	-.14100
Tropical			-3.0325	-2.0873
Non-democratic			.9708	-.2606
R^2 (adjusted)	50.9%	49.8%	45.3%	68.2%
S	2.61201	3.03315	3.87394	2.30902
Observations (cases) used	79	152	95	79
P	.000	.000		.000

The impacts of government expenditure are not as clear in this set of regressions, where regression 5 shows a positive coefficient for government expenditure and regression 8 shows a negative coefficient.

Also notable are the variables of industry and manufacturing as a percentage of GDP. As the percent of GDP from industry increases, the environmental impact measured by CO_2 emissions decreases by .02501 metric tons in model 5 and by .05624 metric tons in model 8. Conversely, as the percent of GDP from manufacturing increases, CO_2 emissions increase by .11328 metric tons, .04557 metric tons, and .08942 metric tons in models 5, 6, and 8, respectively. This is in line with expectations of resource depletion, as the manufacturing sector uses the greatest amount of resources directly and generally pollutes more heavily than other sectors. However, when we look at the scatterplot of CO_2 emissions versus percent of GDP in manufacturing, there is a visible, but weak positive relationship (see Table 5).

Table 5: CO_2 emissions and the manufacturing sector



Returning to the concept of ecological footprint, when looking at the time series data, an alarming trend presents itself. Since 1962 when ecological footprint measurements were first documented, the trend of footprint intensity has been upward. Since 1987, the world as a whole has actually overshot the earth's biological capacity, meaning we are now drawing down resource stores. Since 2003, we have actually overshot the biocapacity by an astonishing 25%, meaning we now need about 1.25 earths to sustain the current level of population and resource use (WWF 2006). In economic terms, the earth's regenerative capacity, or supply of resources, cannot keep up with demand. This leads to loss of biodiversity, habitat degradation, resource depletion, loss of productivity, and endangerment of all species on the planet, especially humans (WWF

2006). The United Nations estimates that the world demand of nature will be twice what the biosphere can provide by 2050, which will most certainly result in ecosystem collapse and complete exhaustion of natural resources (WWF 2006).

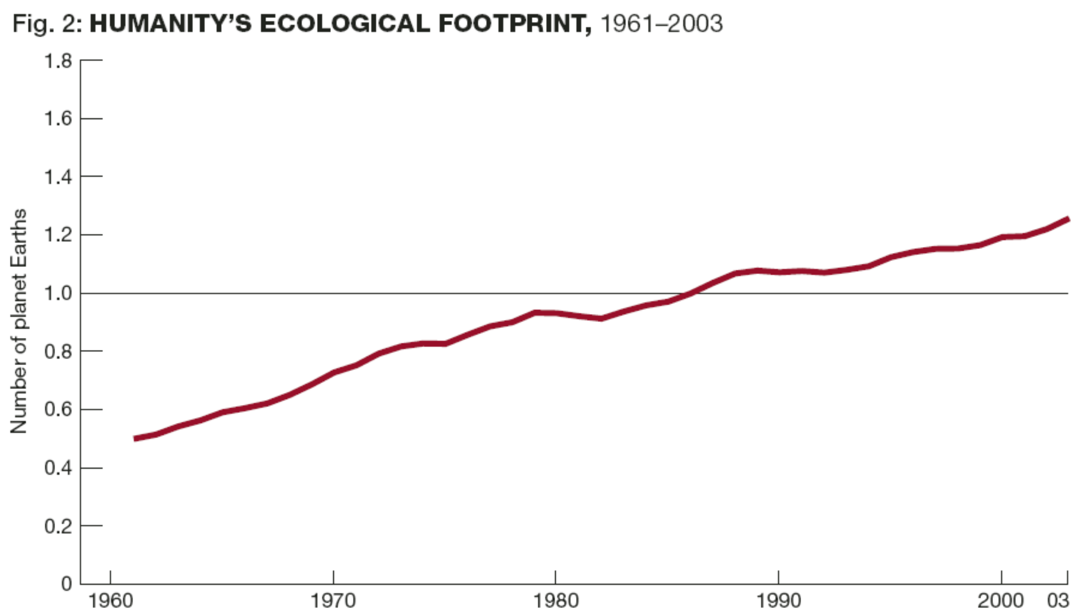
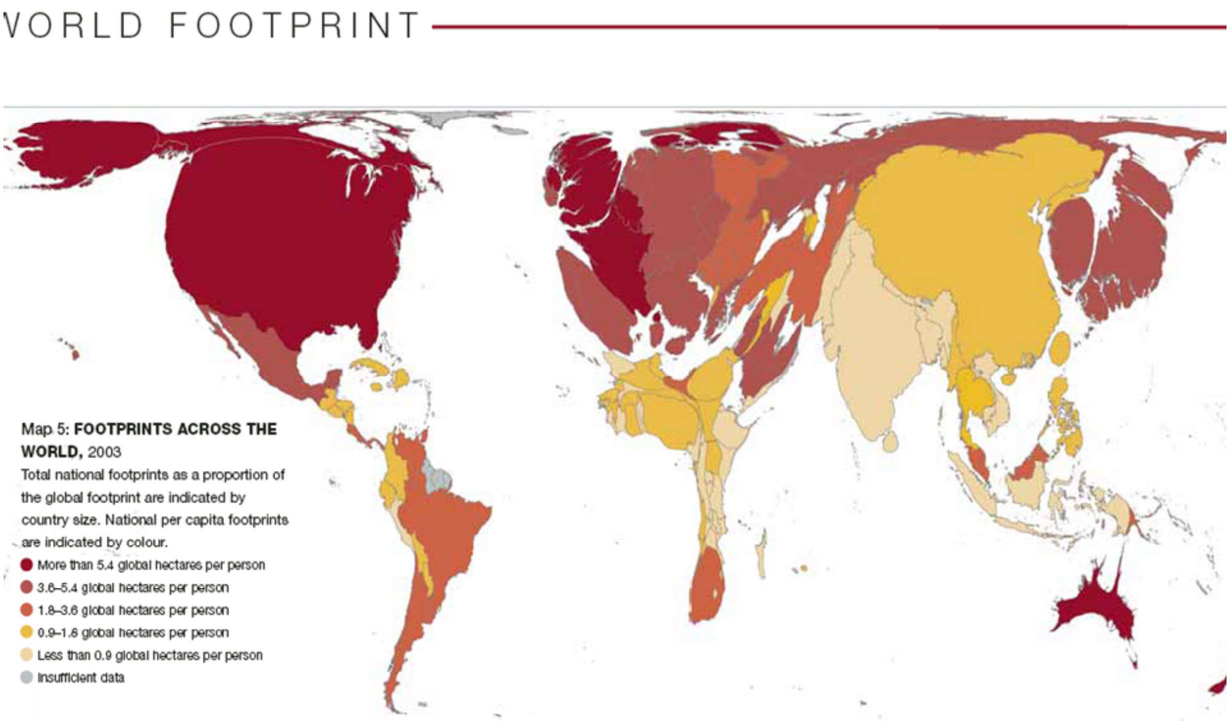


Figure 1: Time series ecological footprint. Courtesy of WWF 2006

In seeking evidence that consumption may be the driver of ecosystem destruction, let us compare two nations based on population alone. The United Arab Emirates (UAE) has the highest Ecological Footprint as of 2003, with just under 12 global hectares per person (a global hectare being the capacity to produce resources and absorb wastes) (WWF 2006). The population of the UAE in 2003 was only 2.5 million people (worldatlas.com 2007). The most populous country in the world, China, with a population of just over 1.3 billion people, only has an Ecological Footprint of less than 2 global hectares per person (WWF 2006). One would expect that the larger the population, the larger the footprint, but this does not hold true. The trend that appears is one of income. Nations with the highest Gross National Income (GNI) (such as

Luxembourg, the United States, Finland, and Canada) have a larger footprint, which would indicate those nations with higher incomes (and ability to consume) have a greater impact on world resources than poorer, more heavily populated nations (World Bank 2006).

Figure 2: World Footprint. Courtesy of the *Living Planet Report*, WWF 2006



When one looks at a simple visual representation of EF (shown above), together with what one knows of populations and economic systems, it is quite apparent that nations with consumer-based societies such as the US, Japan, Australia, and the United Kingdom have the largest impact on the resources of the world. Nations like India and China and regions like central Africa, with very large populations, and less capacity (or ability) to consume beyond subsistence have relatively small footprints. The United States, for instance is disproportionately large in terms of consumption and impact per person on a global scale. This clearly shows that consumption patterns are directly impacting resource use.

Challenges of Empirical Modeling

If the findings of the United Nations, WWF and any other number of organizations and physical models indicate that the world's resource stock is dwindling, how is it that economic models such as those presented herein and others show that consuming more is beneficial, or at the very least, not responsible for degradation? Could it really be that the ecological system benefits from consumption activities or is it more likely that the accepted models are somehow flawed? Anyone who has taken an introductory economics course knows that models are a wonderful theoretical starting point for understanding how markets, industries, and consumers *should* behave. But when applied to real-life, they oftentimes fall painfully short of capturing all variables and relationships, as is the case here, with environmental impact.

To begin, the models used in this study are conglomerations of many different theoretical models and statistical variables. All pertinent and quantifiable variables were included, but there are certainly other variables that play a huge part in environmental impacts that due to time and data restrictions were unable to be incorporated. There are many ecological issues and types of pollution that cannot be easily quantified, and there are many ecosystem services that we are unable to fully model because science has not yet allowed us to fully comprehend them. Additionally, the United Nations has correctly pointed out that, "if natural systems were well understood and behaved in a predictable way, it might be possible to calculate what would be a "safe" amount of pressure to inflict on them without endangering the basic services they provide to humankind," but because they are not predictable, modeling their behavior is next to impossible (UN 2005).

The models were further constrained by the fact that all nations in the world do not consistently report statistics to the United Nations. As such, one cannot fully contend that results are representative of the world as a whole as not all nations have been included in the analysis. Moreover, political changes have resulted in redefinitions of boundaries and borders, which may have skewed the individual country data, gathered in a time series analysis such as this one.

As mentioned before, the technology variable is a “catch-all” variable in the models, accounting for any other changes not included in population or affluence measures. This leaves the variable fairly undefined and results cannot be taken to mean that an increase or decrease of the technology variable necessarily means that technological advance is responsible for the change. Similarly, one cannot interpret the models to mean that technology is the factor driving change. It may, in fact, be any number of variables not specified, but captured in the model. Without disaggregating the variable, there is no way to be sure.

There are also limitations in the data and measurement methods used. Focusing on air impacts, one must consider that there are not an equal number of atmospheric and other monitoring stations in all nations. For example, if the average CO_2 emission figure of nation A is taken from a pool of 500 monitoring stations and the average emission of country B is taken from a pool of only 5 stations, can the two figures really be compared as equals? The relative size of the nation in comparison to others must also be taken into account. Additionally, some pollutants are spatially affecting and some areas experience their impacts more than other areas. This could possibly skew the amounts of pollutants monitored by national stations in direct proximity to strong emissions sources.

Perhaps most importantly, the task of quantifying natural processes, services, and goods is difficult if not impossible. Anyone who has witnessed a late spring morning or a Palouse summer sunset knows that there are certain experiences and services of nature that cannot be priced or in any way quantified. And what of the inherent and intrinsic joy that wilderness gives to humans? What of the value of providing habitat to billions of species, big and small? Or perhaps there is no economic market for a certain forest species, and therefore no interest in saving it, but within the ecosystem it is an integral member of the community. Moreover, how does one put a value to a species or system yet to be discovered? Certainly the field of green accounting is making headway in the quest to economically appreciate nature and its services, but there are many systems that are not fully understood, and many more that cannot be replaced by any current human technology. If this necessary step in modeling cannot be correctly addressed, how then can we ever accurately model and understand the relationships between humans and the environment?

Ethically, when we monetarily try to value something as abstract as the global environment in one model, we fail to appreciate the differences in local biomes and systems. Philosophically speaking, we take away from the value of individuals and processes by lumping them all together and in so doing detract from their intrinsic values (Suzuki 2002). And unlike mathematics or physics, ethical and philosophical “universal laws” do not exist. What is valuable to one individual may carry no worth to another. One’s concepts of right and wrong also vary greatly. If there is no clear undisputed value for non-economic services of nature, can they ever fully be included in economic models to the satisfaction of all interested parties?

Conclusion

As with so many studies before, the results in this case are not as clear cut as hoped, where a finger can be pointed at consumption or a finger can be pointed at population. Empirical modeling seems to produce no concrete judgment one way or the other. How then can we ever draw an empirical conclusion?

The answer is that we cannot, based on current models and methodology. No matter how many regressions are run, how many models are used, or how many variables included, there is an inherent problem with all regressions. On a simple level, consumption and population are two very different things when we speak of them theoretically, but in reality they may be two sides of the same coin. We cannot have consumption without population and economically speaking, there cannot be a population that does not consume. The two variables cannot be completely disaggregated from one another, which is why empirical modeling is incapable of pinpointing the guilty party. Obviously a growing population will have impacts on the environment based on the need for resources to support more individuals. Consumption further compounds a growing population when those individuals begin consuming beyond a subsistence level or beyond the level that the environment can sustain (even if their population numbers are below their respective capacity level). Past that point is when consumption becomes a larger driver of impact than pure population.

This conclusion does not, however, force us to leave the question unanswered. We need only look to another mode of investigation other than the empirical. As EF and the results of the *Millennium Ecosystem Assessment* and *The Living Planet Report* indicate, we have obviously crossed a threshold of sustainability and economic viability.

Regardless of whether current models capture it or not, the physical proof is there: the earth is changing and economics needs to change alongside it. No longer can we rely on models and econometrics to satisfy our quest for understanding impacts and drivers of natural resource change. We must now look to more abstract measurements and pure common sense and logic to help guide our understanding. We intuitively know that drawing on resource caches ultimately depletes that resource. Even with technological advance, it cannot be assumed that we will be capable of recreating the resource artificially for an indefinite period of time. This ultimately means that there is a finite amount of resource available and there are certainly natural thresholds that exist. Even if an empirical model would seem to indicate that we can go on consuming ad infinitum, in a closed system such as the biosphere, we know that this cannot hold true. We must somehow alter the models to take account of that fact.

An all-encompassing survey of the earth's capacity, such as the *Millennium Ecosystem Assessment*, while incredibly time and labor intensive, may be the best alternative to empirical modeling. Physically taking stock of the changes in resources over a period of time can be used to develop better models with more accurate measurements, variables, and effects. The more we understand the functioning and interdependence of earth's systems, the better we can predict their health and development.

Realistically, economic modeling may be a necessity in the face of the time and effort needed to produce a volume of work such as the *Assessment.* If we want to capture the true picture of resource use and what is driving the trends, we must build a better model. In order to do so, we must know or have close approximations of the limits of the natural system's services. But therein lays another great challenge. At this point in time, with current available technology, humanity is incapable of accurately discovering all the resource stores available to us and how far they will stretch given certain situations and variables. Without knowing the limits of this resource equation, it can never truly be solved.

This is not meant to suggest that the entire field of economics is useless, nor that we should give up empirical modeling, but rather in this case, a broader consideration and investigation is needed. We cannot rely on economics alone, including instead the concepts of limits (human and environmental), capacity thresholds, ethical uses and practices, intrinsic values, understanding the future consequences of our actions, and most of all, the concept that growth and having more is not always the wisest goal. When taken into account, these concepts coupled with existing models and knowledge can provide a more complete understanding of the impacts of humans and their consumption patterns on the environment.

DATA APPENDIX A
Unless noted otherwise, all data is from the World Bank *World Development Indicators (2006)***.**

CO_2 emissions: This variable is the national average carbon dioxide emissions in metric tons per capita as measured by atmospheric testing facilities in each nation.

Current Expenditure: Final, total consumption expenditure from all areas of the economy in US$ for the fiscal year.

Deforestation: Presented as forest area rate of change in square kilometers, this variable is derived from adding the cleared land and replanted land to get the net deforestation or forestation rate of a nation. This information comes from Mongabay.com (2007), a clearinghouse of environmental information.

Energy Use: Measured in kilowatt hours of consumption, the accepted measure of energy use.

Environmental strategies or action plans: As found in the United Nations *Human Development Index*, nations who have filed a public, government-sponsored environmental protection and management plan or strategy received a 1 and nations who have never done so received a 0.

GDP (constant 1995$): This figure is the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

GDP per capita: Also in 1995 US dollars, this figure divides GDP per person in the nation giving an average value of GDP share per person.

General Government Final Expenditure: This includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation.

Gross National Expenditure: This variable is the percent of GDP national expenditure makes up and is the sum of all national expenditure, public and private, without taxes, depreciation, or other deflators taken into account.

Household Final Consumption Expenditure: The market value of all goods and services, including durable products (such as cars, washing machines, and home computers), purchased by households. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments and fees to governments to obtain permits and licenses. Here, household consumption expenditure includes the expenditures of nonprofit institutions serving households, even when reported separately by the country.

Industry: This variable is the % of GDP value from the industrial sector of the economy.

Land Area: Measured in square kilometers and gives the entire land area of a nation, including both usable and non-useable land.

Manufacturing: This figure is the % of GDP value from the manufacturing sector of the economy.

Non-democratic. From *The Economist*'s index of democratic countries published yearly. Nations were considered democratic if they fell under the "democracies" or "flawed democracies" categories as defined by the Economist. All other nations were considered to be non-democratic if they fell under the "hybrid regimes" and "autocratic regimes" categories. Democracy in this index is defined as:
1.A competitive, multiparty political system.
2. Universal adult suffrage.
3. Regularly contested elections conducted on the basis of secret ballots, reasonable ballot security and the absence of massive voter fraud.
4. Significant public access of major political parties to the electorate through the media and through generally open campaigning.
Gathered from Economist.com, Democracy Index (2007).

Population: Number of people living permanently in a nation. This variable is also separated into urban and rural populations, describing segments of the population living in cities or in rural/agricultural settings.

Ratification of Climate Change Treaties: Nations who are party to binding, international environmental protection treaties (such as Kyoto Protocol, IPCC Convention on Climate Change, etc.), are given a 1 and nations who have not been party to any current environmental treaties receive a 0. From the United Nations' *Human Development Index (2006).*

SO_2 production: Derived from the Nationmaster.com statistics database, sodium dioxide production is measured in 1000 metric tons per square kilometer of populated land area and is calculated as a national average based on the reports of monitoring stations around the nation.

Tropical: All nations with more than half of their land mass lying within the borders of the equatorial region found within the Tropic of Capricorn to the south and the Tropic of Cancer to the north. Nations with more than half of their land area outside of this area were considered non-tropical. Determined by author.

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