World-Economy Centrality and Ecological Footprint*

Intensive and Extensive Environmental Impacts of the Capitalist World-System

by

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Introduction

Environmental concerns are growing in the early years of the twenty-first century, especially as it relates to the growth of greenhouse gases and the potential consequences of global climate change. NASA reports that 2005 was the warmest year on record, and four of the warmest years have occurred in the past five years (Zabarenko 2006). In fact, the world is argued to be the warmest it has been in a millennium (Connor 2006). Much of this warming is argued to be attributed to the emission of carbon dioxide and other greenhouse gases from human sources.

While some have argued that the climate system has exceeded the point at which attempts to avoid significant climate change can be avoided, it is still necessary to understand the most significant factors driving climate change to potentially avoid more drastic changes. Some researchers have found success linking environmental impact to population and the size of a nation's economy (York, Rosa and Dietz 2003). Others have attempted to use the concepts of the world-systems perspective to address the issue of environmental impact (Burns, Davis and Kick 1997; Burns, Kick and Davis 2003; Burns et al. 1994; Jorgenson 2003; Roberts, Grimes and Manale 2003). While these studies have found significant and strong relationships between environmental impact and the size of a nation's economy or world-system position, they do not adequately compare economic size to world-system position. Is the level of environmental impact merely a factor of the size of the economy, or is it a result of the role a nation plays in the world-economy?

Review of the Literature

A number of researchers have begun to investigate the role of world-economy position as well as the size of a nation's economy with respect to environmental impact. World-systems researchers have attempted to identify the relationship between position in the world-economy and a number of measures of environmental impact. To test various theories regarding environmental impact, York, Rosa and Dietz (2003) include Gross Domestic Product (GDP) as a measure a nation's economic size in their STIRPAT model (explained below).

Beginning with the world-systems research on environmental impact, world-systems researchers have completed a number of quantitative studies with respect to environmental impact. While the world-systems research does tend to support a connection between world-system position and environmental impact, it does have a couple of limitations. First, most of the research does not rely on a consistent definition of position in the world-economy. Second, the number of cases tends to be limited by the complex nature of some of the operationalizations. As a result, this research will rely on a new, more parsimonious definition to ensure the inclusion of the maximum number of cases possible.

Using Kick's (Kick 1984) world-economy classification scheme, Burns et al. (1994) test the effect of world-economy position on deforestation. In addition to world-economy position, the authors also use rural population change, secondary education growth, GDP/captia growth, population change, and growth of the service sector in both regression and path analysis. Based on their findings, the authors contend that rural population growth and increasing total population increased deforestation, especially in the core. Education effects have the greatest impact in the semiperiphery where increased education is associated with decreases in deforestation. Service sector growth is positively associated with deforestation in the semiperiphery, but forestation in the periphery. The authors also found that there is no significant connection between deforestation in the semiperiphery and economic development.

In 2003, Burns, Kick and Davis build on the Burns et al. (1994) deforestation study by addressing issues of population, affluence and technology. The authors are referring to the IPAT model where "environmental *I*mpacts are the multiplicative products of *P*opulation, *A*ffluence . . . and *T*echnology" (York, Rosa and Dietz 2003:280). While the previous study (Burns et al. 1994) is based on Kick (1984), Burns, Kick and Davis (2003) utilize Kick (1987) for the classification of nations in the world-economy. Nations were also limited to those with more than 4% of their lands forested (5% in the previous study). As a result, the number of cases is limited to 73 (10 core, 11 Semicore, 36 semiperiphery, and 16 periphery). The authors focus specifically on the composition of the population as a predictor of deforestation. The authors find a strong effect for world-economy position and GDP/capita. They also argue that the degree of urban population has different effects depending on the position in the world-economy. The semiperiphery and periphery demonstrate negative effects even when controlling for other variables. The authors argue that the semicore has similar results to the core in some models and the semiperiphery in others, claiming the semicore category should not be collapsed with another category such as core or semiperiphery. The predominance of adult populations is associated with greater deforestation. The authors conclude by arguing that the population effects should be contextualized by the various categories of the world-economy.

Again relying on Kick's classification scheme (this time from 1987), Burns, Davis and Kick (1997) attempt to assess the relationship between world-economy position and greenhouse gases, specifically CO_2 and methane. Although the authors claim to be addressing world-economy as a causal factor in greenhouse gases, the hypotheses they develop are not particularly tied to world-systems concepts and theorization. Core and peripheral status is tied to technological development and the standard of living of the occupants of the nations. According to the authors, industrialization, based on Arrighi and Drangel (1986), is argued to move from the core to the semiperiphery, limiting the energy demands of the core. Wallerstein's (2004) views directly clash with this characterization as he argues it is *core processes*, not necessarily industrialization *per se*, that migrate from the core to the periphery when declining profits result from shrinking quasi-monopoly status.

While certain aspects of industrialization may indicate core processes such as high technology, by the time an industrial process moves to the periphery, it has lost its high wage, quasi-monopoly status. The industrial process may be exactly the same in the periphery nation as it had been in the core nation when it was a core process, but the process is much more competitive, low wage and no longer the latest technology once it reaches the periphery.

The authors argue core nations "set production and consumption strategies that aggravate . . . production of industrial CO_2" (Burns, Davis and Kick 1997:442) allowing them a greater ability to produce greenhouse gases. These statements seem to operate against the author's logic (mentioned above) suggesting the declining energy demands in the core and transition of industrialization to the semicore and semiperiphery. In the end, the authors conclude that CO_2 production is monotonically related with position in the world-economy.

J. Timmons Roberts, Peter Grimes and Jodie Manale (2003) focus on the effects of world-economy position and a host of ancillary variables on CO_2 emissions. Roberts et al. (2003) draw links to the world-systems analysis by arguing production in the core has shifted through capital flight and the movement of many polluting industries out of the core. The access and development of high-technology in the core leads to an opportunity to lower pollution levels. The periphery, through the legacy of colonialism and military conquest, has directed production to raw materials and cheap exports. The lack of developed infrastructure drives transportation costs up and encourages the slackening of environmental regulations to keep costs lower for investors. The lowest nations in the periphery with little technology and a high amount of available labor are argued to use less fossil fuels, but also consume a significant amount of forest resources. As a result of these factors, the authors argue that CO_2 emissions/GDP will be greatest in the semiperiphery, representing an inverted U-shaped curve for the world-economy positions of core, semiperiphery and periphery. The authors did find a non-linear relationship between GDP/capita and CO_2 emissions, as well as a non-linear relationship between their composite world-economy position indicator and CO_2 emissions in the expected inverted U-shape. The upward part of the slope was most clearly associated with GDP/capita, while the downward slope was associated more with the world-economy indicator. They argue that the results demonstrate a wide variation in the CO_2 emissions of semiperiphery and upper periphery. The authors also find a strong relationship between military spending/GDP and CO_2/GDP. Percent of labor organized and regime repressiveness is also tied to CO_2/GDP, supporting one of their hypotheses. Contrary to the author's assumptions, population growth is negatively related to CO_2 production. Countries with higher levels of population growth are not necessarily the same nations who are experiencing greater CO_2 production. Export dependence and ties to few trading partners are also correlated with increased CO_2 emissions. Overall, the authors assert that at certain levels of development, technologies and production processes tend to create more efficient production and lower relative CO_2 emissions.

Other research regarding environmental impact has taken a slightly different approach from the world-systems researchers. The approach of York et al. (2003) makes use of the "Ecological Footprint" as a measure of environmental impact to test various theories of environmental degradation. The Ecological Footprint measure, while not overly complex, requires some explanation. The Ecological Footprint is a measure of environmental impact based on the natural resources or "bioproductive capacity" of the planet consumed by people as a result of their activities. The measure accounts for the resource consumption and waste assimilation necessary for a given population in terms of the land area (hectares) necessary to support the population. The components of the Ecological Footprint measure the area of land needed for: growing crops for food, animal feed, fiber, oil and rubber; grazing animals for meat, hides, wool, and milk; harvesting timber for wood, fiber, and fuel; marine and freshwater fishing; accommodating infrastructure for housing, transportation, industrial production, and hydro-electric power; and burning fossil fuel (Wackernagel and Rees 1996:9-10; Wackernagel et al. 2002b:9266). What is so unique about the Ecological Footprint measure is that it is able to attribute the environmental impact of the components it addresses to the nation (or other population unit) that consumes the resources. The Ecological Footprint "accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land/water area required from nature to support these flows" (Wackernagel and Rees 1996:3). In this way, the Ecological Footprint accounts for the imports to a nation while it subtracts the exports from the nation's Ecological Footprint. This technique gives a more accurate accounting of the actual environmental impact of the nation in question because it attributes the environmental impact to the consuming nation regardless of the origin of the product or activity.

Because the Ecological Footprint measure is relatively new, few authors have used it to analyze the impact of the world-economy position on the Ecological Footprint. Richard York, Eugene Rosa and Thomas Dietz (2003) set out to test the ability of various theories of the environment to predict Ecological Footprint. In addition to the theories of modernization, political economy, world-systems analysis and human ecology, the authors provide a parsimonious "STIRPAT" model. The STIRPAT (*ST*ochastic *I*mpacts by *R*egression on

*P*opulation, *A*ffluence, and *T*echnology) model is a modification of the IPAT model in stochastic form due to the inclusion of an error term. In the authors' STIRPAT model, technology is included in the error term, and the variables are logged in order to create an elasticity model. The STIRPAT model includes the log of population and the log of GDP per capita. A quadratic STIRPAT also includes the quadratic of GDP per capita. The world-economy position is defined in the research based on the level of dependency indicated by official development assistance. Core nations are considered those that do not receive assistance. Semiperiphery nations are those nations that receive assistance less than .5 percent of their GDP. The periphery includes all nations not included in the other two categories. The authors found firm support for the STIRPAT model while the world-economy variables were non-significant in the analysis. Given that previous world-systems' research has found support for the environmental impacts of world-systems variables, perhaps the simplistic nature of York et al.'s (2003) world-system variable is partially responsible for the lack of significance. While development aid may be associated with position in the capitalist world-economy, it is not central to the logic and mechanisms perpetuating the inequitable relations within the world-economy.

Andrew Jorgenson (2003) focuses specifically on the world-economy position and the Ecological Footprint. Using structural equation modeling, Jorgenson assesses the connection between Ecological Footprint per capita, world-economy position as defined by Kentor (2000), and three mediating variables: income inequality (GINI), percent of total urban population, and literacy rate. Jorgenson argues that his hypotheses are supported. World-economy position is found to have a positive effect on per capita footprints due to the more productive economies and articulated markets. The GINI measure is negatively related to Ecological Footprint, argued to be a result of the lower consumption of low wage workers in the periphery. The results also supported the argument that urbanization is positively related to Ecological Footprint because cities are viewed as key markets and concentrated areas of economic and industrial activities. The author's assertion that literacy is related to responsiveness to consumerist ideologies is also supported. Jorgenson estimates a second model that includes GDP per capita. GDP per capita, world-economy position and all of the mediating variables remain significant except literacy rate. Jorgenson concludes that "per capita footprints are largely a function of a country's position in the core/periphery hierarchy of the world-system" (Jorgenson 2003:380), but his model adds GDP per capita and does not test for the effects of GDP per capita absent of his world-economy position variable.

While the previous research appears to indicate world-system position is related to environmental impact questions remain to be answered. What is the relationship between GDP and world-system position with respect to environmental impact? Roberts et al. (2003) argued that high population growth is not necessarily linked with increased CO_2 production. Findings like this and others require theoretical explanation. What explains the differences between various types of environmental degradation? The rest of this paper will attempt to address these issues through greater attention to theoretical specification and operationalization of the world-system position variable.

Operationalization of World-Economy Position

Beginning with the basic theoretical concepts outlined by Wallerstein, it is possible to situate a new operationalization in firm theoretical grounding. Wallerstein begins with an axial division of labor that is comprised of an occupational hierarchy of core and periphery processes. The distribution of core and periphery processes is organized geographically through the processes of unequal exchange which drains surplus value from the periphery to the core, perpetuating the relationships. Strong states are integral to the geographic distribution of core processes in specific regions of the world-economy and the ability to limit certain regions of the world-economy to peripheral processes. The historical development of the capitalist world-economy did not occur instantaneously, but proceeded over time through the process of incorporation. Incorporation has both an extensive component with respect to the actual geographic inclusion of regions in the capitalist relational processes and an intensive component regarding the intensification of the inequality in the capitalist relational processes (Wallerstein 1982:98-9).

Developing empirical indicators of the axial division of labor is very difficult. As mentioned above, a number of authors attempt to address Wallerstein's conceptual contribution of core and peripheral processes, but they tend to focus on products. Wallerstein has provided such definitions of core and periphery processes that include high wage, high technology, quasi monopolies, etc. (Wallerstein 1976a:462; Wallerstein 2004:28), but very little global data deals with these specific issues. While some data exist on wages from the World Bank WDI database (World Bank 2001), a number of cases are missing including Australia, Canada, Germany, Netherlands, United States and United Kingdom.

Tracking the indicators of unequal exchange is equally as difficult. Defining unequal exchange itself has proved difficult empirically, while the actual data are elusive. For Wallerstein, the focus on unequal exchange is the flow of surplus value from the periphery to the core. It could be argued that nations are exhibiting the negative effects of unequal exchange when the value of their imports exceeds the value of their exports, but there are two problems with this view. First, core and semiperiphery nations are able to maintain trade imbalances over the short-run while maintaining their relative position in the world-economy. Second, the importance is specifically focused on the inequality of exchanges and not the actual monetary amount of the nation's total trade. A peripheral region may maintain a relative trade balance in monetary units while the peripheral region consistently loses surplus value in the transactions due unequal exchange. Part of the definition of core processes is quasi-monopoly status, but defining commodity classifications with respect to quasi-monopoly status would be time consuming and possibly fraught with classification errors.

Some authors have attempted to include political power in their operationalizations of world-economy position. Unfortunately, many of these attempts have focused on the military aspect of state strength. Government expenditures on military, military imports or exports, military or political conflict and indicators of repressiveness of the government are examples of indicators used by previous researchers. Wallerstein's focus, however, is on the preservation and promotion of quasi-monopolies. While military tactics are admittedly part of the process of protecting quasi-monopoly status of core processes, it is not the only or most important method. Economic dominance and control of international political decision-making bodies are also others, with broader application to more nations at the same time.

Incorporation is another possible means to define position in the capitalist world-economy. While Wallerstein argues geographic (extensive) incorporation was effectively completed by the beginning of the twentieth century (Wallerstein 1976b:351), extensive incorporation continues. The relations between the regions of the world-economy deepen. While incorporation could be measured by the expansion of capitalist accumulation in the core and the official colonial incorporation into the world-economy of colonial territories, intensive incorporation could also be viewed as a relative integration in the capitalist relations of the world-economy.

While nations and regions were incorporated into the capitalist world-economy at different times, their specific environmental and historical trajectories determined the degree to which they became ensnared in the unequal relations between core and periphery processes in the axial division of labor[1] (Bunker and Ciccantell 1999; Bunker and Ciccantell 2003). While timing in the incorporation of the world-economy is important, the development of core and peripheral processes within a nation, articulated with strong and weak state relations, helps to determine the degree to which nations are incorporated in the world-economy. While a historical analysis of each nation's incorporation into the world-economy would be helpful to understand how a nation was incorporated, as well as its present position in the unequal relations in the axial division of labor, it is not easily undertaken. Another possibility which has been undertaken in various ways by other authors is an attempt to locate nations' positions in the world-economy through the network of world trade.

Terence Hopkins cautions against singling out trade as *the* form of the relationship between the core and the periphery (Hopkins 1982:152).

> "Accordingly, to let the relation which 'core-and-periphery' designates slip into the background is to let the labor process as it operates on a world scale slip into the background as well. One place in particular where this sort of slippage seems to occur frequently is in discussion of 'trade' between 'core' and 'periphery'. With the latter pair as classificatory terms, we say, 'Here's a core-country and here's a periphery-country; now, how are they related? Why, through 'trade'.' And with that, a set of activities and interactions we call 'trade' ceases to be just one of many ways in which the interrelations linking the partial-production-operations formative of 'cores' and those formative of 'peripheries' are actualized, in given times and places. And instead 'trade' (almost invariably as 'market trade') becomes

[1] This is the focus of the research by authors such as Bunker and Ciccantell (1999, 2003). The historical trajectory of world-system hegemons can be traced to raw material access and control of transportation routes as a result of military or technological dominance.

the form of *the* relationship between *the* core and *the* periphery."

Hopkins offers strong caution against the reduction of the world-economy to trade relations, but it may be possible to situate trade in unequal exchange of core and peripheral processes. Perhaps just as core states and peripheral states can be used as a shorthand for core and peripheral processes at the nation state level (Wallerstein 2004:28), trade can be used as a shorthand for world-economy relations as long as the inequitable nature of the relations is retained and the researcher refrains from positing trade as *the* world-economy relation and *the* defining feature of the world-economy. While using trade relations as an indicator, it must be acknowledged that they do not represent the sole relationship of the world-economy, but act as a proxy for the relations of unequal exchange between core and peripheral processes. World trade as represented by total imports and/or exports can possibly describe the relations of unequal exchange and the relative position of nations in those relationships if the relative strength of each nation in the world-economy is accounted for in a network of world-economic relations. No single measure can capture completely the historical operation of the capitalist world-economy, but it may be possible to develop a parsimonious indicator that may act as a proxy for world-economy relations in broad cross-national research.

While world trade as expressed as imports or exports has been used by world-systems analysts, few tend to use more than mere ties between nations with respect to trade. Breaking from authors who use simple ties, Tieting Su (2002) conducts a network analysis of world trade data to determine the structure of the world-economy over time. To construct a trade network, Su adds imports to exports. Su then calculates, for each nation, the proportion of its total trade that is exchanged between each other nation. In this way, Su argues that a high percentage of trade with one nation may indicate a nation's dependence on its trading partner. Su then constructs a matrix for network analysis including only ties where trade levels are 10% or greater for all of the years of the study. The author uses network analysis specifically to determine the composition of trade blocks in four separate years: 1928, 1938, 1960 and 1999. While Su's analysis appears to confirm the author's hypothesis that the world-economy consists of waves of trade interdependence and trade fragmentation, Su's technique points to a promising indicator of world-economy position.

Although Su's analysis is "designed to fathom trade structures" (Su 2002:360), it is possible to use a similar technique to construct an indicator of world-economy position. One measure, centrality, is especially useful for this type of analysis. The centrality measure in network analysis counts the number of ties between "actors" in the network and can be viewed as a measure of inequality between trading partners in the world-economy. "It is based on this theoretical and empirical ground that centrality is used to identify major trading partners" (Su 2002:360). Trade centrality can be understood as a measure of the centrality of a nation in the relations of unequal exchange between core and periphery processes described by Wallerstein. The more central a nation is in the network of relations in the world-economy, the more likely the nation is dominated by core processes and using this advantage through unequal exchange to better its position in the capitalist world-economy. More central nations are deepening their intensive incorporation into the relations of the world-economy to further benefit from unequal exchange. While mere centrality of ties may indicate the connectedness of a nation within the network, the relative trading strength of each nation adds another crucial dimension. The command of trade flows, both import and export, represent the historical development of the world-economy into gaining zones and losing zones (Wallerstein 1983:32). Large trade flows could be understood to represent both the ability to gain through unequal exchange through the amount of trade, but also the rewards accumulated to a nation through the unequal exchange of core and peripheral processes. The processes of the operation of unequal exchange in the world-economy are inextricably linked to the outcomes. Unlike GDP, however, a measure of trade centrality including trading strength is more than a simple measure of economic outcome. While the extensive nature of incorporation was effectively completed in the early 20th century, trade centrality captures two elements of the intensive nature of the world-system. Increasing trade ties and the expanding disparity of the volume of world trade both demonstrate the intensification of relations of unequal exchange within the world-economy. While there will be some expected correlation with other measures of economic strength such as GDP, the combined nature of trade strength and trade ties provides a measure that captures, with simple data and methods, both the sheer size of an economy and the centrality of the nation within the capitalist world-economy.

Because of the applicability and the parsimony of its design, trade centrality will be used as a measure of position in the world-economy in this paper. Network analysis has been used by a number of world-systems analysts, especially in the case of block modeling (Kick 1987; Smith and White 1992; Steiber 1979). Block modeling techniques, as constructed by previous authors, tended to include a variety of variables rather than a single indicator. The trade network for this paper will be comprised solely of import data from 1999 in the International Monetary Fund's (IMF) Direction of Trade Statistics (DOTS) (International Monetary Fund 2000). The IMF DOTS is available in print form which requires data entry by hand. Imports and exports representing the trade between nations in millions of US dollars are listed for each included nations. Total volume of trade, imports and exports, is necessary to represent the combined trade role played in the relations of unequal exchange in the world-economy. Unfortunately, import and export data are compiled differently and are not necessarily equivalent because of inconsistencies in data collection. Export data is calculated as "free on board" (f.o.b.) while import data is "cost including insurance and freight" (c.i.f.). The data collection contains a number of inconsistencies including: differences in the classification concepts and detail, when the data is recorded, the valuation of the goods, processing errors and issues of coverage such as free trade zones (International Monetary Fund 2000). Nemeth and Smith (1985) also suggest the use of import data due to the greater accuracy of import figures. For these reasons, the construction of the trade centrality focuses solely on import data. IMF DOTS import data is entered in matrix form listing imports on the vertical axis while the horizontal axis would, technically, indicate exports to the importing nation. The import matrix is used to calculate a sum of both imports and a measure of exports by transposing the import matrix and adding the transposed matrix (exports) to the import matrix. Nations are included in the matrix for use in the network analysis if the IMF DOTS provided trade data for a specific nation. If the IMF did not provide a complete trade account for a specific nation, it is deleted from the analysis even if several nations reported trade with the nation. As a result, nine nations (Afghanistan, Botswana, Eritrea, Laos, Lesotho, Mongolia, Namibia, Nepal, North Korea) are missing compared to the dependent variables' data sets, Ecological Footprint and CO_2 Emissions (defined below).

The IMF DOTS trade matrix is imported into the UCINET 6 network program (Borgatti, Everett and Freeeman 2002) to create the network centrality variable. Since the data is transposed and added to itself (described above), the resulting matrix is symmetrical. The value of combined imports and exports is retained in the matrix. UCINET 6 is used to calculate Freeman's Degree Centrality with the IMF DOTS trade matrix. The resulting variable will be referred to as *World-Economy Centrality* (W-E Centrality). Freeman's Degree Centrality measures the number of ties for each actor with others in the network (Hanneman 2001:61).

Since the data contains a monetary value for trade between nations, Freeman's Degree Centrality sums the values of all the ties for each actor in the network (Borgatti, Everett and Freeeman 1992:82). Therefore, not only is the number of connections important, but the relative importance (import/export trade volume) of trading partners increases the value of the actor's centrality measure. In general, nations whose trade is low in volume with other nations will have lower centrality scores than nations that have high trade volumes with their trading partners.

Returning to world-systems analysis, nations with numerous trade ties have greater opportunity for profiting from unequal exchange, and the total volume of trade as a result of the ties indicates the success of a nation as a "gaining zone." Although a significant amount of intercore trade accounts for sizeable portions of trade volume, the fundamental relationship of inequality holds with nations relying primarily on peripheral processes, and their low volume of trade value and few ties can be understood as an indication of the subordinate role in the world-economy.

In addition to the world-economy position variables, a number of other variables are relevant to the analysis. Since environmental impact is being measured, some control variables need to be added that may have effects on the dependent variable. First, the assumption of the IPAT model suggests that population contributes to environmental degradation. York et al. (2003) support the idea of population as a significant contributor to environmental impact. The more people a nation has, the greater the environmental impact. High population in the periphery is theorized (below) to be the result of the operation of the world-economy. While this paper does not attempt to answer this theoretical assumption, the effects of population on environmental impact are nonetheless important, and population's effect relative to the other included variables is significant to the analysis in this paper. Land Area operates as a control variable to account for the possibility that the more land area that exists to be degraded within a nation, the greater the potential environmental impact. Greater population densities from limited land area will also tend to have greater environmental impact. Therefore, Population and Land Area, as provided by the *Living Planet Report* (Wackernagel et al. 2002a), shall both be included.

Another variable that must be included in the analysis is GDP. While many world-systems researchers have used GDP in the operationalization of world-economy position (Arrighi and Drangel 1986; Kentor 2000; Roberts, Grimes and Manale 2003), others have looked at the impacts of GDP on environmental impact (Burns et al. 1994; Jorgenson 2003). While some authors contend GDP does have an effect, York et al. (2003) argue GDP is one of the most salient. A clear test of the effect of GDP relative to world-economy position is necessary because of weaknesses in the previous research. Jorgenson (2003) merely adds GDP to his existing regression model without determining GDP's independent effects. York et al. created a world-economy position variable from World Bank WDI international aid data, but the variable was dummy coded with cleavages between positions in the world-economy not firmly rooted in the theoretical contributions of Immanuel Wallerstein. Below, the role of the size of an economy, GDP, and world-economy position are explained. It will be argued that GDP and World-Economy Centrality have different effects on environmental degradation.

Theoretical Backdrop

To understand the anthropogenic effects of people's interaction with nature, it is first necessary to conceptualize how people's interaction with the environment is organized. Karl Marx (1971; 1973; 1977; 1981a; 1981b; 1998) discussed at length this exact problematic in both his early and later works. For Marx, society was organized through the necessary metabolic interaction with the environment. In order to meet their needs, people must obtain the necessary elements from nature through the use of their labor. The process of obtaining these necessary elements from nature through labor is metabolic interaction. The very creation of society in its primitive origins resulted from the necessary interchange with the environment to obtain and create the means essential for survival. The social nature of people is a result of the organization of relationships between people to meet their daily needs, based on the given environmental circumstances. The interaction with nature is part of the dialectical relationship between social organization and the material-environmental circumstances. Environmental conditions shape the social organization, and the act of obtaining and creating the means to life through a specific, historic social organization alters the given environmental conditions. Neither aspect remains static as both social organization and material-environmental circumstances transform as a result of the dialectical interchange.

Capitalism is the contemporary social organization dictating the form of our relationship with nature. Capitalism is a form of social arrangement based on capital accumulation, primarily through wage labor, that orders the extraction, production and distribution of the means of life through a metabolic interaction with nature. Like any other social organization, capitalism must take natural elements and transform them into the means necessary for life, in other words engage in a metabolic interaction with nature. Marx argued that the inherently expansionary capitalist production process necessitates an ever increasing use of nature's elements. “The more capitalist production is developed, bringing with it greater means for a sudden and uninterrupted increase in the portion of the constant capital that consists of machinery, etc., and the more rapid the accumulation (particularly in times of prosperity), the greater is the relative overproduction of machinery and other fixed capital, the more frequent the relative overproduction of plant and animal raw materials" (Marx 1981b:214). To deal with the natural limits of nature's productions, capitalists are left with three possible solutions: extract raw materials from greater distances, expand production of the raw material on a greater scale, and replace the natural elements with surrogates or more economical use of waste products (Marx 1981b:213-4). In this way, "The natural materials which are exploited productively (and which do not form an element of capital's value) i.e. soil, sea, mineral ores, forests, etc. may be more or less severely exploited, in extent and intensity, by greater exertion of the same amount of labor-power, without an increase in the money capital advanced" (Marx 1981a:431).

Thus, the metabolic interaction Marx described can be understood to have extensive and intensive components. The way people organize the extraction of elements from nature for people's needs assumes historically specific geographic (extensive) and temporal (intensive) dimensions. Geographic, extensive, means that capitalism expands the amount of nature's elements extracted to meet the ever increasing drive for accumulation. To meet the needs of accumulation, ever greater regions and materials are brought under capitalist production. New fields are incorporated into agricultural production, more mine shafts are dug, more forests are cleared, etc. Simply put, production is expanded.

Similarly, capitalist production attempts to increase the intensity of the metabolism with the environment (the speed at which nature's elements can be extracted and transformed) by altering the social relations and technology of production. Marx discussed natural processes such as wine fermentation and the ripening of food plants. Little labor is necessary for the natural processes to occur, but the capital must lie idle while the processes take place. Capitalists seek to shorten these natural processes to limit the idle time of their capital (Marx 1981a:316-8). "The turnover period can often be shortened to a greater or lesser extent by the artificial shortening of the production time. Examples of this are the introduction of the chemical in place of open-air bleaching, and more effective drying apparatus in the drying processes" (Marx 1981a:317). In short, production is intensified.

The extensive and intensive needs of capital for ever increasing expansion lead to "an irreparable rift in the interdependent process of social metabolism, a metabolism prescribed by the natural laws of life itself" (Marx 1981b:949). See Foster (1997; 1999; 2000; 2002) for a deeper discussion of Marx's concept of metabolic rift. The metabolic rift, both extensive and intensive (defined below) results from the accumulation logic of capital that necessitates ever greater expansion of profit, and subsequently the use of nature. The extensive rift results from the geographic expansion of the metabolic interaction due to the increasing demands of capital to bring ever more of nature under production and the further division of town and country. As more of nature is involved in capitalist production, the distance between extraction and consumption grows, nature is depleted in one region while waste is concentrated in another. Metabolic cycles are disrupted as nutrients and resources extracted from one area are not returned, but are deposited in another distant geographic region, often as waste.

Marx specifically outlined the extensive rift as the division of town and country and the problem of capitalist agriculture (Marx 1977:637-8; Marx 1981b:195,949-50). The concentration of people in cities and the agricultural production in rural areas "disturbs the metabolic interaction between [people] and the earth, i.e. it prevents the return to the soil of its constituent elements consumed by [people] in the form of food and clothing; hence it hinders the operation of eternal natural condition for the lasting fertility of the soil" (Marx 1977:637). The expansion of capitalist production reaches out further and further geographically for the elements necessary for production, while the end products are concentrated in the regions of accumulation where the natural elements are not returned to their origin. Not only are the elements not returned, they may become waste in the area where their consumption occurs. Marx states, "In London, for example, they can do nothing better with the excrement produced by 4½ million people than pollute the Thames with it, at monstrous expense" (Marx 1981b: 195). By creating this extensive rift, the natural metabolic cycles are broken as the elements are not reentered into the cycle.

The intensive rift results from the increasing speed of the use of nature's elements in the capitalist production process. Capitalists attempt to increase their profits by reducing the amount of time necessary for the production of their products through the intensification of the use of nature in the production process. The intensification of the use of nature disrupts natural metabolic processes by destabilizing the relationships within natural processes. The resulting rift is the disproportionate depletion of nature's elements and concentration of waste, at the point of extraction, from the intensification of the metabolic interaction with nature.

The intensive rift is slightly different in that it results from increasing the rate of the productions of nature. Natural processes are quickened and intensified, creating disturbances in natural cycles. The disturbance in natural cycles is the intensive metabolic rift. The most notable example of the intensive rift is the disruption of global climate as a result of the anthropogenic production of CO_2 from burning fossil fuels. CO_2 is naturally produced by volcanic venting, decomposition of organic matter, forest fires, etc. but is also removed from the atmosphere and oceans through a number of interrelated processes (Lovelock 2000; Smil 1997). The use of fossil fuels has enabled capitalism to greatly increase the rate of production and accumulation, but at a potentially high cost. The CO_2 that could be released by the burning of all accessible fossil fuels is ten times greater than exists currently in the atmosphere (Weart 2004). Instead of using the available solar radiation and biomass, fossil fuels are used as a form of stored sunshine, intensifying the energy available for use in capitalist society. By producing anthropogenic CO_2 levels out of step with natural climatic processes, fossil fuel use produces an intensive metabolic rift exhibited by the disrupted climate. Because of the complexity of the natural climatic processes, the long term effects of industrial CO_2 production are difficult to perceive, but it appears as though climatic change as a result of anthropogenic CO_2 emissions is a well established fact in the scientific community (Hunter 2002; Vitousek 1994; Weart 2003).

The intensive and extensive metabolic rifts are linked, and can be found in the same production process as a result of their common origin in the expansionary accumulation logic of capital. Capital intensive agriculture provides an example of both an intensive and extensive metabolic rift. The division of town and country and the removal of nutrients from the soil to a distant location where it is concentrated as waste represent the extensive rift. With the intensive rift, the application of intensive agricultural production techniques to increase yield and profit result in an imbalance of soil chemistry, beyond the overall depletion of the soil. While providing certain nutrients such as nitrogen, capitalist agriculture depletes others, reducing the long-lasting fertility of the soil due the imbalance created in the soil chemistry.

While it may appear that technology is responsible for the metabolic rift, it is the accumulation logic of capitalism that is specifically responsible. The accumulation logic of capital demands that technology is put toward uses that increase profit and are inherently expansionary, necessitating ever greater and more intense use of nature. “Capitalism maximizes the throughput of raw materials and energy because the greater this flow–from extraction through the delivery of the final product to the consumer–the greater the chance of generating profits” (Foster 1994:123). Potentially, societies organized under a logic that is not inherently expansionary could employ technology in a fashion that does not lead to a metabolic rift.

The Integration of Theory and Method

Prior to outlining the dependent environmental variables used in this analysis, the theoretical roots of the contribution of world-economy position will be discussed. The world-systems literature is virtually silent when it comes to applying the theoretical contributions of Immanuel Wallerstein to the study of cross-national environmental impacts. Many researchers claim a world-systems perspective, but few root their analysis in Wallerstein's conceptualization when developing their hypotheses. This paper will attempt to develop an analysis of environmental impact based on a combination of Marx's metabolic interaction and Wallerstein's theoretical perspective.

While Marx discusses both people's metabolic interaction with nature and the metabolic rift, the nature of the dependent variables, the components of Ecological Footprint, do not allow for the direct testing of the metabolic rift. Only processes indicating an intensive or extensive metabolic interaction are present within the Ecological Footprint components. The ten components of the Ecological Footprint include: CO_2 Emissions, Nuclear Power, Hydro Power, Fuelwood and Charcoal, Forest excluding fuelwood, Built-up Land, Water Withdrawls, Grazing Land, Fishing Grounds and Cropland. While the *effects* of the components of the Ecological Footprint can be linked to intensive and extensive metabolic rifts such as climate change or soil degradation, the variables themselves represent the intension and extension of people's metabolic interaction with nature, driven by the capitalist accumulation logic. In other words, CO_2 Emissions and Grazing Land do not represent the rift itself, but are the result of the capitalist accumulation logic and identify processes associated with the intensive and extensive metabolic interaction with nature. Since the Ecological Footprint components do not represent the rift, the terms "intensive process" and "extensive process" will be used to describe the processes associated with the intensive and extensive metabolic interaction.

As discussed above, the metabolic interaction has intensive and extensive components. The extensive metabolic interaction is geographic in nature and refers to the need to incorporate increasingly greater shares of nature in the capitalist production process. As a result of production under capitalism constantly increasing, the point of extraction of natural resources becomes divided from the point of consumption of those resources - the division of town and country.

The intensive metabolic interaction is specifically speeding up the natural processes to increase efficiency and decrease the amount of time necessary for production. Karl Marx acknowledged the pressures of capital to increase efficiency, specifically in terms of the use of waste in the production. "Marx (1981b:196-7) described the use of rags in the making of woolen garments and also the use of the byproducts of the chemical industry" (Prew 2003). But Marx also argued that it did not improve capital's relation with nature. Capitalist production, "for all its stinginess, . . . make[s] it very wasteful of material resources, so that it loses for society what it gains for the individual capitalist" (Marx 1981b:180).

Marx (1981a:316-8) also argued capitalists seek to shorten the unfolding of natural processes such as chemical bleaching and other technological advances. Through the use of technological means, the intensive metabolic interaction means that natural processes are accelerated causing disruptions in natural metabolic cycles. By reducing the time necessary for natural processes, profit is increased because capital is idle for shorter periods of time and throughput is increased.

The extensive and intensive processes can be readily tied to Wallerstein's analysis of the capitalist world-economy. Wallerstein's begins his analysis with the axial division of labor rooted in the unequal exchange between core and periphery processes. The axial division of labor and unequal exchange is expanded and deepened through the process of incorporation. While extensive incorporation was effectively completed by the early 20th century, intensive incorporation continues to deepen the relations of unequal exchange[2]. While at one pole, a gaining zone develops; at the other, grows a losing zone.

In the losing zone, poverty and inequality grow. Peasants and indigenous peoples are forced from productive land as it is incorporated into the capitalist production process through the ownership of wealthy landholders. Those forced from the land have two options: either move to less productive land and attempt to maintain a subsistence lifestyle or move to urban areas in an effort to gain employment. Neither option reduces poverty; rather, they tend to worsen it. The direct result of the increasing poverty and dislocation originating from unequal exchange is the expansion of an extensive metabolic interaction through the expanding use of natural resources, and subsequently increasing the distance between where the resources are extracted and where they are consumed. Extensive processes can be linked to the increasing poverty of the peripheral regions. People must travel farther for Fuelwood and graze animals on lands (Grazing Land) not suitable for food production. Increasing urbanization in the form of Built-up Land expands the division of town and country through the increasing reliance on rural agricultural production (Cropland) and other natural resource needs like lumber (Forest).

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[2] Extensive and intensive incorporation are not equivalent to extensive and intensive metabolic processes, despite the similar terminology. While both concepts deal with geographical and temporal dimensions, they address different phenomena.

The extensive processes are furthered by another result of the operation of unequal exchange. In the capitalist world-economy, the operation of unequal exchange can be argued to lead to growing poverty and stunted economic growth in peripheral regions. As a result, the demographic transition to low birth rates has been delayed in peripheral regions. Most peripheral regions, while able to lower infant mortality in appreciable numbers, were unable to secure the economic standing necessary to lead to reduced birth rates. As a result, populations have grown rapidly in peripheral regions (Foster 1994:15-16). These two factors, poverty and high population growth rate, combine to intensify the extensive processes in the peripheries, such as the consumption of food in the form of fish, grazing land and cropland. The impact of extensive processes is worsened by the rate of population growth.

The environmental impact in the core is qualitatively different from in the periphery. While the operation of unequal exchange accumulates wealth in the gaining zone, environmental issues develop from both extensive and intensive processes. The metabolic interaction increases extensively from the increased economic resources as a result of unequal exchange. The accumulation logic, central to capitalism, spurs increasing consumer demand for the products of the capitalist production process. To meet the needs of capital accumulation and the relatively wealthy consumers of the core demands that more of nature is brought into production. Larger economies allow for greater consumption of natural resources in the form of commodities. As more people to move to cities, urban areas grow (Built-up Land), aided by industrialized agriculture (CO_2 Emissions). Like in the periphery, the extensive processes such as Built-up Land, Cropland and Forest are linked to the increase in wealth in the core.

While the operation of the capitalist world-economy produces similar results in the core and periphery with respect to extensive processes, intensive processes can be directly linked to the core processes described by Wallerstein. Core processes are in their nature intensive processes. Core processes, as high technology, quasi-monopolies (Hopkins and Wallerstein 1987:770; Wallerstein 2004:27-9), use production processes that intensify the use of nature, i.e. intensive processes. Core processes are dependent on increased energetic throughput created through fossil fuel burning, nuclear power or other forms of energy such as hydro-electric dams. By burning "stored sunshine," production processes in the core are able to access energy unavailable through the current bio-productivity of the earth, by some estimates, hundreds of times more than current bio-productivity (Dukes 2003). Fossil fuel use is one of the most significant means to intensify the throughput of production. As a result, CO_2 represents a means through which capital intensifies the metabolic interaction with nature. Nuclear and hydrological power are similar strategies to increase production intensively. Hydrological power, however, because of its dependence on available waterways, may be more closely related to sufficient land area to provide suitable locations for hydro-electric dams.

Compared to regions of the world with few core processes, especially in regions of great poverty, energetic needs are met with less technology and more natural resource consumption. Instead of intensifying the metabolic interaction, extensive processes are used to meet energetic needs in the periphery, burning forest as fuelwood for example. Consumption of high tech, core processes occurs primarily in the core due to the relatively wealthier consumers. Core processes are directly linked to intensive processes with respect to the metabolic interaction with nature. Therefore, the production of CO_2, an intensive process produced in regions with high technology quasi-monopolies, should be found to be a direct function of the role in the world-economy, more so than a measure of the sheer size of the economy such as GDP.

Some have argued that production in the core, being more technologically advanced, would be more efficient and therefore less environmentally unsound than production elsewhere (Mol 1997). Although quasi-monopolies and core processes use the most technologically advanced production processes, environmental degradation continues despite increased "efficiency" in production. Core processes may be more environmentally efficient than their peripheral counterparts, but increased accumulation in the core allows for (actually necessitates) increasing environmental degradation as a result of increasing demand for the commodities produced with more efficient practices (Clark and Foster 2001). The existence of quasi-monopolies and high technology not only allows for production from nature on a grander scale, it also allows the more intensive use of nature's products. The high technology, quasi-monopolies of core processes attempt to increase efficiency in terms of usable byproducts of production and shortening natural metabolic processes. In this way, greater efficiency actually intensifies the use of nature in the production of goods. Greater ability for throughput results in a greater overall use of nature due to the ever expanding accumulation logic of capital.

Water use is an environmental impact that should be closely associated with population, but water is not just used for drinking. Industrial processes use water in great quantities. The question of whether water use is an example of an extensive or intensive process depends on whether the water is drawn in one region to be consumed in another, such as distant reservoirs that feed large urban areas, or systematically depleted in order to increase the productive output, as in irrigation agriculture in semi-arid regions. Whether water use is more associated with extensive or intensive processes is unclear with respect to the Ecological Footprint measure of water withdrawls which does not provide a clear distinction of water use.

While the operation of the capitalist world-economy can be theoretically linked to both population and national economic size, the environmental impacts resulting from the extensive processes may be more closely associated with population and economic size (GDP) than world-economy position itself. The operation of the capitalist world-economy may be antecedent to the development of large populations and economic power, but population and GDP would be expected to have more proximate effects on natural resource use associated with the extensive processes. Cropland use, fuelwood burning, forest consumption and built-up land can be more closely tied to the economic resources needed to consume the goods and the populations that put pressure on natural resources. Intensive processes differ from extensive processes since intensive processes are more directly connected to the operation of the capitalist world-economy, specifically the presence of core processes within a nation.

Focus should not be solely on the production processes, but should include transportation as well. The use of fossil fuels allows capital to span great distances cheaply. As a result of subcontracting, capitalists no longer need to relocate the physical infrastructure in a number of industries, but can transport goods to be assembled where the costs of production, especially labor, are lowest. The finished product is then shipped to its intended market. The amount of time saved in transportation allows goods to travel great distances and is an example of intensive processes that allow capital to increase the throughput of natural resources to increase profit. Transportation is closely tied to intensive energy practices and CO_2 emissions.

As a result of the operation of the capitalist world-economy, both extensive and intensive metabolic processes exist. Like population, greater economic production and consumption, indicated by GDP, are associated with extensive processes. What is unique about core processes are the specific intensive processes associated with the intensification of the use of nature's resources. The more core a nation, the greater the intensive processes such as CO_2 production are found within that nation. Despite the fact that this paper uses nation states instead of specifically core/periphery processes, the use of nation state as "shorthand" for core should still demonstrate the relationship between core status and intensive processes.

The defining feature of the operationalization of world-economy position used in this paper is based on the degree of a nation's incorporation into the capitalist world-economy. The operationalization of world-economy position as trade centrality as an indicator of incorporation in the capitalist world-economy should be consistent with the presence of core processes within a nation. The concentration of core processes within a nation, protected and supported by a strong state, places a nation in an advantageous position in the axial division of labor within the capitalist world-economy. Nations that are not central actors in the capitalist world-economy will be less likely to be dominated by core processes.

While Wallerstein argues semiperiphery nations are defined by a relatively even distribution of core and periphery processes, certain anomalous cases can be pointed out. Large geographic nations like the US contain within them peripheral processes, but a nation like Belgium may appear to be more core because it contains relatively less peripheral processes than the US. While certain anomalies exist, especially geographically smaller nations within Europe, the general principle of relatively even distribution of core and periphery processes still holds for most semiperipheries. Core nations will have greater total core processes, while the semiperiphery will have less and, in general, a relatively even distribution of core/periphery processes. The environmental impact of the semiperiphery should be less than the core but greater than the periphery which contains almost exclusively peripheral processes. Speaking more specifically, the world-economy position should be closely tied to intensive processes because of the more direct link between core processes and intensive processes. Extensive processes, while influenced by world-economy position, will be more closely linked to population and GDP.

The focus on total core processes compared to the relative distribution between core and periphery processes is an important theoretical point. Environmental impact, especially intensive, should be tied to the number of core processes within a nation state's boundary. The unique position in the world-economy given by the amount of core processes within a nation determines the specific form and degree of environmental impact of a nation. For the purposes of this paper, the totality of the characteristics of the nation state is important, not relative measures such as ratio of core to periphery processes or per capita influences. Like argued above, this is not to say that the ratio of core to periphery processes is not important, but the total amount of core processes takes precedence in this analysis because it focuses on nation state effects. Since the nation state is the focus of this analysis, the total environmental impact of the core processes contained within the nation is important, not relative measures such as per capita environmental impact.

Likewise, total economic power such as GDP is also important and used in this analysis. Nations vary in the inequality that exists within them, the populations that they must support, and the land area available for demographic expansion. While some nations may be able to support larger populations due to land area (Brazil compared to Belgium for example), the relative wealth, as indicated by per capita GDP, is not as important as the total economic power of the nation in the world-economy. China, while its per capita economic indicators may be lower than less populous nations in Europe for example, has a greater impact in the world-economy by the sheer size of its economy and its more central location in the axial division of labor in the capitalist world-economy. Like centrality in the world-economy, the total economic wealth of a nation gives it sway in capitalist world-economy, not the relative wealth of its citizens as in per capita economic figures. While population has effects, they will be parsed out by including population as a control variable. The total impact of a nation's world-economy centrality and GDP on *total* environmental impact is the focus of this analysis.

Previous attempts to develop theoretical rationalizations for the effect of the world-economy lacked an overall continuity with the theoretical perspective of Immanuel Wallerstein. Authors like Burns, Davis and Kick (1997) suggest shifting industrialization patterns are responsible for the differential environmental impacts. World-systems analysis is not required for such suppositions which would be equally as explicable by ecological modernization arguments, proposing new production technologies and shifts to economic growth separated from natural resource use will alleviate environmental pressures (Mol 1997). It is argued here that the theoretical combination of world-systems analysis and intensive/extensive processes provides a much closer adherence to the contributions of Immanuel Wallerstein while providing more specific links to environmental degradation than previous formulations.

This paper argues that the operation of the capitalist world-economy has direct effects, not only on generalized environmental impact, but also on the specific types of processes related to environmental impact. The operationalization of the world-economy, defined as World-Economy Centrality, will have direct effects on measures of environmental impact. Since the theory suggests environmental impact will vary regarding extensive and intensive processes, it is necessary to identify measures of environmental impact capable of making these distinctions. Fortunately, the Ecological Footprint measure can be disaggregated into various measures of ecological impact representing extensive and intensive processes. While GDP and population should be related to extensive processes such as built-up land, World-Economy Centrality should be more closely associated with intensive processes such as CO_2 emissions.

Environmental Impact Variables

In order to test such theoretical assertions, it is necessary to identify an indicator of environmental impact. While a number of potential measures exist, few are as versatile as the Ecological Footprint. One environmental impact measure is based on assessing the share of net primary production (NPP) appropriated by societies. "NPP is the amount of energy left after subtracting the respiration of primary producers (mostly plants) from the total amount of energy (mostly solar) that is fixed biologically" (Vitousek et al. 1986). Societal metabolism tracks the flow of energy and material through a society (Fischer-Kowalski and Amann 2001). As described above, Ecological Footprint is a measure of the bio-productive land area necessary to support the consumption of a given population or political-economic unit.

While other indicators measure the environmental impact of production activities occurring within a nation, the Ecological Footprint targets the amount of environmental impact associated with a *specific* nation's consumption regardless of its place of origin. In other measures, CO_2 emissions, deforestation or energy use are attributed to the nation where such environmental impacts occur. Ecological Footprint, on the other hand, tracks the environmental impact of consumption within a particular political-economic unit, regardless of where the production occurs. If deforestation in Brazil occurs to produce pig iron consumed in the US, the Ecological Footprint from the deforestation is attributed to the US, not Brazil. Imports and exports are tracked in the measure to provide an account of only the environmental impact that can be attributed to the population of the state, regardless of where the environmental impact occurs. Neither NPP or societal metabolism allows for this type of tracking of environmental impact. The Ecological Footprint also has a readily available data set not provided by the other potential measures of environmental impact.

While authors have previously used Ecological Footprint per capita (Jorgenson 2003; York, Rosa and Dietz 2003), none have broken down the Ecological Footprint into its various components to analyze the effect of the independent variables on the separate components. In this paper, the complexity of the capitalist world-economy necessitates that the various components within the Ecological Footprint be parsed out to identify the individual impacts of world-economy position, as well as the control variables (Land Area, Population and GDP), on each component of the Ecological Footprint. Ecological Footprint measures are taken from Wackernagel (2002a) and transformed from per capita variables to national measures. To get the National Ecological Footprint measures, each separate component, as well as the total Ecological Footprint, are multiplied by the population figure within the Ecological Footprint data set. The natural log for each measure is also computed. For some measures (Fishing Grounds, Fuelwood, Nuclear Power and hydo-power), the data contains "0"s and required "1" to be added to all of the cases before taking the logarithm to avoid missing variables. Because adding "1" to these four variables causes unusual patterns in the data and results, the analysis is conducted with both "1" added to the variable and without. For example, Figure 1 provides the scatterplots for the Hydro Power variable before and after logging. The other logged components of the Ecological Footprints display similar patterns.

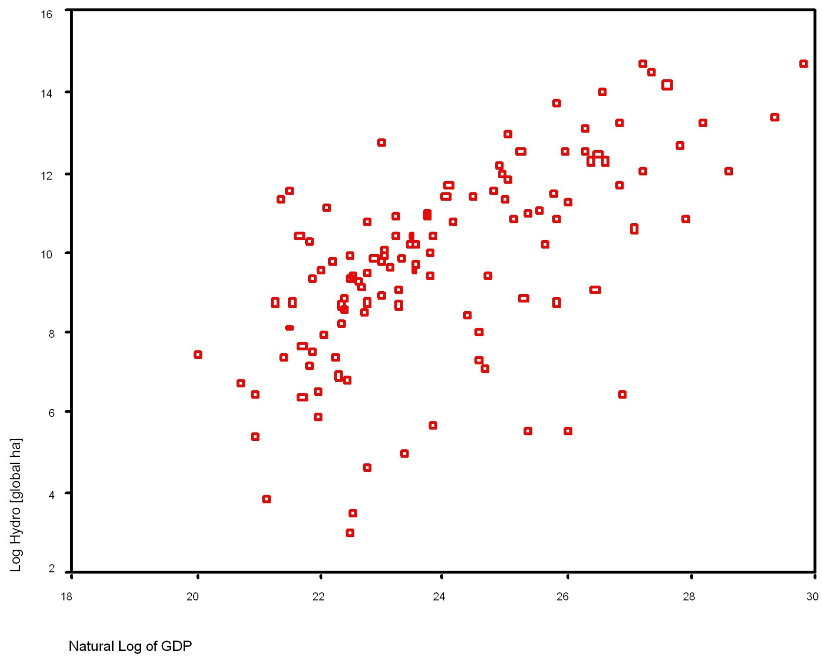
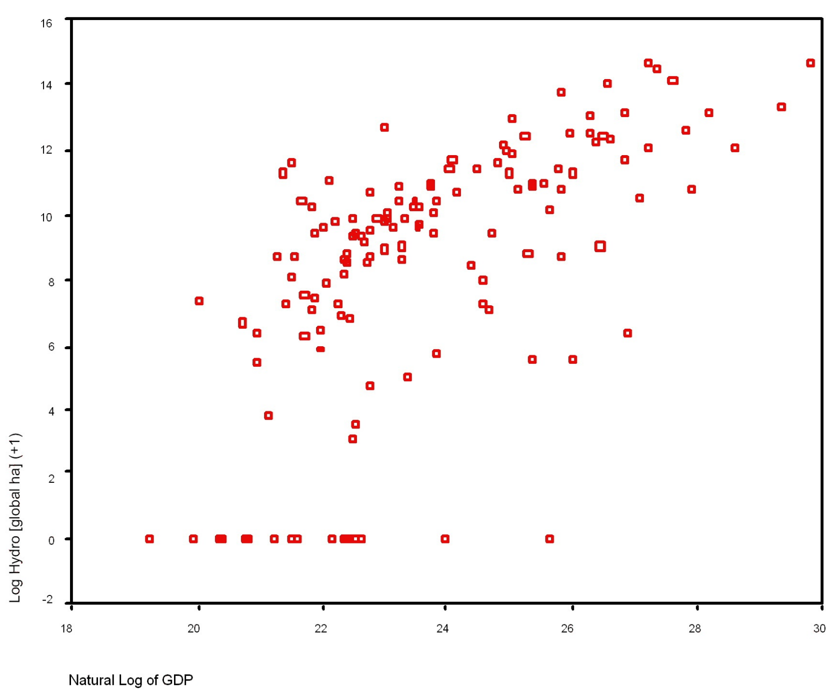


Figure 1. Scatterplots for the Log of Hydro Power (above) and Log of (Hydro Power +1) (below). After adding one to Hydro Power to eliminate missing cases, the resulting "0"s appear as a line of cases at the bottom of the scatterplot. Because of the irregularity, data analysis is conducted with both variables for comparison.



Since missing cases during logging occurs with two of the three energy variables, a new variable is created that added CO_2 Emissions to Nuclear Power and Hydro Power. This new variable (CO_2, Nuclear and Hydro) contains no "0" data points and is also logged. As a comparison, the CO_2 Emissions from the World Bank (2001) WDI database is also included. Since Ecological Footprint tracks the environmental impact of what is consumed within a nation state regardless of origin, CO_2 Emissions from the WDI should vary given that the WDI CO_2 Emissions measure the total CO_2 produced in a nation regardless of the end consumer. WDI CO_2 Emissions are also logged.

Hypotheses

The salience of world-economy position, as defined by the World-Economy Centrality measure will be used to predict environmental impact in the form of WDI CO_2 Emissions and the various components of Ecological Footprint. The following hypotheses can be derived from the above general statements.

H1: Measures of Ecological Footprint representing intensive processes will be more closely associated with World-Economy Centrality, specifically CO_2 Emissions, Nuclear Power, and Hydro Power.

H2: Measures of Ecological Footprint representing extensive processes will be more closely associated with Population and GDP, specifically Fuelwood, Forest, Built-up Land, Cropland, Fishing Grounds and Grazing Land.

Regression Models

Standard OLS regression will be used for all models. The regression models tested are based on the parsimonious STIRPAT model of York et. al (2003). York et. al (2003) include the Natural Log of Population and the Natural Log of GDP per capita in the basic STIRPAT model. Unlike the basic STIRPAT model, World-Economy Centrality is also included to test for effects related to world-economy position beyond the sheer size of the economy. The Natural Log of Population and total GDP, not GDP per capita, were included in the equation. For the purposes of this paper, the total effects of GDP are important for understanding a nation state's total impact. By using total GDP, it is more comparable to world-economy position which is determined not by per capita influences but by its total world-economy strength relative to other nations. The Natural Log of Land Area is also included as a control variable. The dependant variables in this model include not only total National EF and CO_2 Emissions, but also EF disaggregated into its constituent parts as found in the *Living Planet Report* data (Wackernagel et al. 2002a). The focus of these models is to get a clearer understanding of the role of GDP and World-Economy Centrality with respect to extensive and intensive processes. The components of the Ecological Footprint allow the creation of models to test the hypotheses regarding the specific predictiveness of GDP and extensive processes as well as World-Economy Centrality and intensive processes. Each component of Ecological Footprint, as well as the combined energy footprint and WDI CO_2 Emissions, is tested with the full model and also with GDP and World-Economy Centrality in separate regressions, keeping the nations constant in each model. By testing the effects of GDP and World-Economy Centrality separately, it is possible to avoid any multi-collinearity effects and discern the impacts of each variable separately, with the Natural Log of Land Area and the Natural Log of Population as control variables.

<u>Results</u>

The regression models address the impact of World-Economy Centrality on National Ecological Footprint to discern possible specific effects with respect to extensive and intensive processes. Two overall analyses are conducted. First, four variables (Natural Log of Land Area, Natural Log of Population, Natural Log of World-Economy Centrality and Natural Log of GDP) are included in regressions against the components of the National Ecological Footprint (see Table 2). Because of the potential multi-collinearity, multi-collinearity diagnostics are included in the regression analysis. Although the results indicate caution should be exercised, the Tolerance is .072 and .060 for Natural Log of World-Economy Centrality and Natural Log of GDP, respectively, for nearly every regression. Although highly correlated, the Tolerance does not exceed the more stringent .05 cutoff for exclusion from the equation for multicollinearity. The VIF is 13.826 and 16.747 for Centrality and GDP, respectively, in most cases. Second, Natural Log of World-Economy Centrality and Natural Log of GDP are included separately with the control variables on each National Ecological Footprint component and CO_2 Emissions from WDI data.

To set a baseline, Population and Land Area are regressed against National Ecological Footprint (Table 1). Only Population is significant with an r-square of .765 for the model. All models use one-tailed tests for significance because the models include the expected direction for the relationships.

Table 1. World-Economy Position Indicator Variables Regression: Land Area and Population Only

Dependent Variable: Natural Log of National Ecological Footprint: 1999

Independent Variables	*b*	S.E.	Beta
Natural Log of Land Area	.0704	.062	.074
Natural Log of Population	.924***	.073	.821
(Constant)	.01987	.646	

R Square = .765
N = 114

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

The results of the analysis tend to confirm the theoretical assertions that World-Economy Centrality, GDP and Population can be found to have specific effects with respect to intensive and extensive processes (Table 2). In the full model on total National EF, all variables are significant. Both World-Economy Centrality and GDP are positively related with National EF. When CO_2 Emissions and other energy variables are tested, the results take and interesting turn. With the energy variables (the combined CO_2, Nuclear and Hydro variable, as well as CO_2 from EF data, and CO_2 from WDI data), World-Economy Centrality remains significant and strongly predictive, while the Natural Log of GDP and Natural Log of Land Area are no longer significant.

The hypothesis that world-economy is more strongly associated with intensive processes in terms of environmental impact tends to be supported. The fact that GDP is no longer significant suggests that the intensive process associated with CO_2 emissions is more a result of the operation of world-economy and specifically core processes than the sheer size of an economy. Interestingly, there does not appear to be a significant difference in the CO_2 emissions from the National Ecological Footprint data or the WDI data. This could suggest that a net balance of Ecological Footprint from CO_2 emissions exists between imports and exports. If a balance exists between the amount of CO_2 emissions produced for export and consumed through imports, the CO_2 produced within a nation would tend to be similar to the footprint of CO_2. Alternatively, the vast majority of CO_2 emissions may occur within nations. While there may be some exchange of CO_2 emissions, the footprint from imports appear to be defrayed by exports.

Table 2. Disaggregating the Ecological Footprint Measure

Independent Variables	Natural Log of National EF			Natural Log of CO_2, Nuclear and Hydro [EF data]		
	b	S.E.	Beta	*b*	S.E.	Beta
Log Land Area	.104***	.023	.114	.04286	.061	.032
Log Population	.501***	.035	.444	.259**	.092	.156
Log Centrality	.09593*	.047	.136	.739***	.123	.710
Log of GDP	.314***	.053	.434	.131	.138	.123
(Constant)	-7.732***	.833		4.350*	2.187	
R Square			.961			.875
Number of cases			129			129

Independent Variables	Natural Log of CO_2 from Fossil Fuels [EF data]			Natural Log of CO_2 Emissions [WDI data]		
	b	S.E.	Beta	*b*	S.E.	Beta
Log Land Area	.04017	.062	.030	.05897	.061	.045
Log Population	.285**	.094	.173	.272**	.093	.167
Log Centrality	.744***	.125	.721	.771***	.124	.755
Log of GDP	.101	.141	.096	.06287	.140	.060
(Constant)	4.923*	2.236		-.150	2.214	
R Square			.867			.867
Number of cases			129			129

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

Table 2. Disaggregating the Ecological Footprint Measure (cont.)[3]

	Natural Log of Nuclear Power EF			Natural Log of (Nuclear Power EF +1)		
Independent Variables	*b*	S.E.	Beta	*b*	S.E.	Beta
Log Land Area	-.0864	.103	-.049	-.0865	.103	-.049
Log Population	.139	.155	.064	.139	.155	.064
Log Centrality	.636**	.208	.467	.635**	.208	.466
Log of GDP	.573**	.234	.411	.573**	.234	.411
(Constant)	-7.863*	3.704		-7.865*	3.704	
R Square			.791			.791
Number of cases			129			129

	Natural Log of Hydro Power EF			Natural Log of (Hydro Power EF +1)		
Independent Variables	*b*	S.E.	Beta	*b*	S.E.	Beta
Log Land Area	.372**	.147	.246	.201	.223	.092
Log Population	.105	.217	.057	.320	.336	.118
Log Centrality	.05498	.297	.000	.310	.451	.183
Log of GDP	.579*	.331	.484	.524	.509	.301
(Constant)	-9.057*	5.218		-9.789	8.040	
R Square			.446			.366
Number of cases			116			129

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

[3] Because the cases lost due to logging (Lesotho and Somolia) are also missing from the other included variables, the number of cases remained the same for Nuclear Power EF.

Table 2. Disaggregating the Ecological Footprint Measure (cont.)

	Natural Log of Biomass EF (Fuelwood and Charcoal)			Natural Log of (Biomass EF +1) (Fuelwood and Charcoal)		
Independent Variables	*b*	S.E.	Beta	*b*	S.E.	Beta
Log Land Area	.181	.165	.120	.03670	.235	.017
Log Population	1.120***	.252	.597	1.539***	.352	.595
Log Centrality	-.171	.332	-.147	-.188	.475	-.115
Log of GDP	-.194	.377	-.162	-.232	.535	-.139
(Constant)	13.781*	5.975		15.101**	8.458	
R Square			.320			.252
Number of cases			121			125

	Natural Log of Forest EF (excl. fuelwood)			Natural Log of Built-up Land EF		
Independent Variables	*b*	S.E.	Beta	*b*	S.E.	Beta
Log Land Area	.009048	.088	.008	-.01129	.032	-.013
Log Population	.735***	.132	.517	.782***	.049	.717
Log Centrality	4423E-02	.177	.050	9.045E-02	.066	.132
Log of GDP	.290	.200	.318	.315***	.074	.450
(Constant)	5.245*	3.158		5.461***	1.169	
R Square			.647			.917
Number of cases			128			129

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

Table 2. Disaggregating the Ecological Footprint Measure (cont.)

Independent Variables	Natural Log of Water Withdrawals EF (2000 estimate) *b*	S.E.	Beta	Natural Log of Grazing Land EF *b*	S.E.	Beta
Log Land Area	.07162	.091	.055	.456***	.068	.465
Log Population	.817***	.137	.507	-.0218	.095	-.018
Log Centrality	.344*	.183	.347	-.367**	.093	-.483
Log of GDP	.06076	.206	.060	.758***	.079	.972
(Constant)	7.226*	3.251		-6.398**	1.586	
R Square			.704			.700
Number of cases			125			129

Independent Variables	Natural Log of Fishing Grounds EF *b*	S.E.	Beta	Natural Log of Cropland EF *b*	S.E.	Beta
Log Land Area	.04159	.092	.032	.130***	.029	.154
Log Population	.390**	.139	.243	.598***	.043	.574
Log Centrality	.300	.186	.299	.04218	.058	.066
Log of GDP	.368*	.210	.357	.207**	.066	.310
(Constant)	.594	3.312		7.259***	1.035	
R Square			.694			.929
Number of cases			129			129

*$p<.05$ **$p<.01$ ***$p<.001$ (one-tailed tests)

Nuclear Power and Hydro Power appear to be a little more complex. The Natural Log of GDP and the Natural Log of World-Economy Centrality are both significant while the logs of both Land Area and Population are not with respect to Nuclear Power. Hydro Power, on the other hand, is not significant on any variable when "1" is added prior to logging. This is possibly due to the unusual pattern displayed in the data described above. The untransformed log of Hydro Power is significant on the log of Land Area and the log of GDP. As suggested above, the availability of hydro-electric plants may be determined largely by environmental conditions and having a nation where geographic size is large enough to likely provide waterways suitable for hydro-electric plants.

Fuelwood, as predicted, is largely attributable to the effects of Population. The Natural Log of Biomass EF is only significant on the variable Log of Population. Interestingly, Population is also the only significant variable when it comes to the Natural Log of Forest EF that excludes fuelwood. Forest use, although used for infrastructure in core regions, appears to be tightly tied to population pressures regardless of whether it is used for fuelwood or cleared for other reasons. The pressures on forests can be tied to the delay in the demographic transition and the pressures people place on the local environment when the operation of the world-economy deprives them of other means of livelihood. This is consistent with the theoretical arguments above indicating forest use is more closely tied to the extensive rift and likewise population effects. Forest use does not seem to depend on economic size, GDP, whether it is used for fuelwood or consumed for other purposes. This suggests that population is primarily responsible for the extensive rift created by forest use.

On three other variables, the Natural Log of World-Economy Centrality is not significant. Build-up Land, Cropland and Fishing Grounds appear to be less strongly tied to World-Economy

Centrality than the other variables, especially Population and GDP. Population and GDP are significant predictors of Built-up Land, Cropland and Fishing Grounds while World-Economy Centrality is not. The results are consistent with the theoretical expectation that Built up Land, Cropland, and Fishing Grounds are expected to be related to extensive processes. Grazing Land, on the other hand, is significant with Land Area, GDP and World-Economy position, not with Population. Interestingly, the World-Economy Centrality variable exhibits a relationship with Grazing Land EF opposite of the expected direction (negatively related with Grazing Land). A possible explanation for this anomaly exists within the *Living Planet Report* (Wackernagel et al. 2002a:8). "Some low income countries had a comparatively large grazing land footprint because a high proportion of their land was less productive than the world average, and suitable only for grazing." Grazing Land appears to be tied to extensive environmental processes in the effect of GDP, but also the land area necessary to support grazing as a productive activity. The issue of greater centrality in the capitalist world-economy leading to a lower Grazing Land Ecological Footprint raises questions. Possibly, greater economic resources lead to greater grazing land footprints while, simultaneously, the reliance on peripheral processes (due to marginal land biocapacity) also require greater use of grazing land for nutritional needs.

The actual predicted relationship of water use with GDP, Population and World-Economy Centrality is ambiguous. Water use is certainly necessary for everyday consumption needs, but it is also used, as in irrigation agriculture, to intensify the productions of nature. The results of the regression tend to indicate that both extensive and intensive processes are present. The Natural Log of World-Economy Centrality and Population are significant on the Log of Water Withdrawls, while GDP is not. While the relationship with Population is expected, it appears as though the position in the world-economy is also positively related with water use, indicating that there may be some intensive processes present as a result of the operation of core processes.

Overall, the theoretical predictions and hypotheses indicating the intensive and extensive processes are supported. World-Economy Centrality is more closely related with CO_2 Emissions and the combined energy index including Nuclear and Hydro Power. Extensive processes such as Forest use, Cropland and Built-up Land are more closely associated with Population and GDP. The results support the theoretical argument that the operation of the capitalist world-economy leads to different environmental impact effects. While GDP and population are argued to be a function of the historical development of the capitalist world-economy, their environmental impacts are more proximate when it comes to extensive processes such as forest use, cropland for food production and land built-up for shelter and transportation. World-economy position is argued to be more closely tied to intensive processes because of the more direct connection to the presence of core processes. Due to the high technology nature of core processes that allow more intensive use of nature, environmental impacts such as CO_2 emissions that result from high technology core processes can be more directly associated with the operation of the capitalist world-economy in general and the World-Economy Centrality variable in specific.

The final part of the analysis attempts to compare the effects of World-Economy Centrality and GDP to further illustrate the separate intensive/extensive effects and also the comparable predictiveness of World-Economy Centrality with respect to GDP. By separating the variables, GDP and World-Economy Centrality, effects of multicollinearity may be avoided. What is striking about the results of the equations (see Table 3) is the closeness of explained variance by the Natural Log of World-Economy Centrality and the Natural Log of GDP. The r-square is practically identical on three of the National Ecological Footprint variables (difference of .001 or less). Where there are differences, they tend to support the arguments in this paper that World-Economy Centrality should be more predictive of the Ecological Footprint associated with intensive processes. In fact, the greatest differences between the variables are found on the CO_2 Emissions and other energy variables, with World-Economy Centrality having the greater r-square (with the exception of Hydro Power). The differences between the two variables in terms of explained variance is strikingly similar. Twelve of the sixteen r-squares differ by .015 or less between the GDP and World-Economy Centrality regressions. Of the remaining four, World-Economy Centrality has a lower r-square than GDP (by .039) only with respect to Grazing Land EF. The three others are related to energy production as mentioned above.

Table 3. **Independent Impact of W-E Centrality and GDP on Ecological Footprint Variables.** Each dependent variable was run in two different models. The first included the Natural Log of World-Economy Centrality with the Natural Log of Land Area and the Natural Log of Population. The second included the Natural Log of GDP with the Natural Log of Land Area and the Natural Log of Population. Cases (129) were held constant in each regression. Provided here are the r-square values for the outcome of each regression equation.

Independent Variable	Natural Log of W-E Centrality R^2	Natural Log of GDP R^2
Natural Log of National EF	.949	.959
Natural Log of CO_2, Nuclear and Hydro EF	.874	.839
Natural Log of CO_2 from Fossil Fuels EF	.867	.830
Natural Log of CO_2 Emissions (WDI data)	.867	.826
Natural Log of Nuclear Power EF	.781	.775
Natural Log of Nuclear Power EF (+1)	.781	.775
Natural Log of Hydro Power EF	.431	.446
Natural Log of Hydro Power EF (+1)	.361	.364
Natural Log of Fuelwood EF	.319	.319
Natural Log of Fuelwood EF (+1)	.250	.251
Natural Log of Forest EF (excl. fuelwood)	.641	.646
Natural Log of Built-up Land EF	.905	.916
Natural Log of Water Withdrawals EF	.704	.695
Natural Log of Grazing Land EF	.644	.683
Natural Log of Fishing Grounds EF	.686	.687
Natural Log of Cropland EF	.923	.929

Not only is the explained variance close between the two variables, the r-squares nearly match the r-square in regressions with all four variables included. For example, the r-square is .867 for the Natural Log of World-Economy Centrality on both CO_2 emissions variables (WDI data and EF), while the r-square is exactly the same for the regressions with all four variables (Table 2). Given the close predictiveness of World-Economy Centrality and GDP (with the noted exception of Grazing Land and better predictiveness of World-Economy Centrality with respect to the intensive processes), it may be possible to substitute World-Economy Centrality for GDP in equations dealing with environmental impact. The complete nature of the explained variance in the reduced model with World-Economy Centrality suggests that it can be used in models excluding GDP without significant reduction in the explanatory power of the model.

The results of this final model have very interesting implications for the theory. While the theory predicted GDP should be more closely associated with extensive processes (and these predictions tend to be supported), the differences between GDP and World-Economy Centrality are small, except in the case of Grazing Land. World-Economy Centrality can be said to be more predictive of intensive processes, but it also very close to GDP in its predictive capacity with respect to extensive processes. Perhaps, World-Economy Centrality is not only predictive of intensive processes, but also is predictive of extensive processes in most cases. Because of the specific results with respect to CO_2 emissions and other intensive processes, GDP does not appear to be as versatile as World-Economy Centrality. Although this paper does not test the theoretical assertions above that GDP is largely a result of the operation of the world-economy with more proximate effects on extensive environmental impacts, the close predictiveness between GDP and World-Economy Centrality may be a result of the relationship between the operation of the capitalist world-economy and economic outcome, GDP.

Central to understanding specific environmental impacts, the theoretical concepts regarding core processes outlined by Wallerstein tend to be supported. The operationalization of the World-Economy Centrality is intended to capture the total core processes contained within nation state boundaries without actually necessarily defining or enumerating them. Centrality in the axial division of labor within the capitalist world-economy as indicated by import/export trade centrality is intended to capture the essence of the total amount of core processes within a nation state by identifying a nation's position in the relations of unequal exchange between core and periphery processes in the world-economy. Nations with greater total trade and a more central location in the network of trade should contain the greatest number of core processes, given the logic of the theory. Concentration of core processes is argued to increase a nation's relative standing due to unequal exchange. Centrality in the world-economy is indicative of this advantageous position.

Centrality, and the core processes it represents, are crucial in understanding the differential environmental impacts cause by the extensive and intensive processes. As argued above, intensive processes are associated with core processes and their high technology production that allows the greater intensive use of nature's resources. CO_2 emissions are the most prominent example. The predictive superiority of World-Economy Centrality over a measure of sheer economic strength, GDP, supports the theoretical arguments regarding the impacts of intensive processes resulting from nature of core processes in the capitalist world-economy. The extensive processes related to GDP and population also tend to be supported. Intensive processes associated with energy use and intensified use of natural resources such as CO_2 emissions, nuclear power and water withdrawls are associated with World-Economy Centrality in the results of this analysis. Likewise, as predicted, the extensive processes related to forest use, built-up land, cropland, etc. were all associated with GDP and population. Overall, the distinction of extensive and intensive processes combined with the theoretical perspective of Wallerstein is upheld.

Conclusion

This paper tests the effects of the theoretical arguments regarding the extensive and intensive processes with respect to World-Economy Centrality, GDP and Population. The benefits of the World-Economy Centrality variable allow the testing of the major consideration of this paper: the specific effects of the extensive and intensive processes. Extensive processes refer to the metabolic interaction characterized by the expansion of capitalism separating the source of extraction from the point of consumption. Intensive processes refer to the metabolic interaction characterized by the intensification of capitalist production process that disrupts natural metabolic cycles. GDP and population are argued to be associated with extensive processes because resources are increasingly extracted on greater geographic scales from nature to meet growing economic and population demands. Intensive processes are associated with the core processes that intensify the use of nature and disrupt natural metabolic cycles. World-Economy Centrality measures the amount of core processes present within a nation. The use of the National Ecological Footprint measure, disaggregated, allowed a test of the specific effects of the extensive and intensive processes.

The results of the analysis in this paper are consistent with the theoretical assertions regarding intensive and extensive processes. CO_2 emissions were clearly more associated with the World-Economy Centrality variable than GDP. Population and GDP, however, were associated with the indicators of extensive processes such as cropland and forest degradation.

The theoretical assertions regarding world-economy position and the intensive and extensive processes are supported by this analysis.

While the population and the size of a nation's economy are important predictors of environmental impact, they are not the only significant factors. The distinction of extensive and intensive processes allows a more complex picture to emerge. World-economy effects are unique with respect to intensive processes, specifically energy intensive practices that lead to CO_2 emissions. This paper demonstrates something new: the specific environmental effect of position in the world-economy above and beyond the effect of the size of a nation's economy and its population. CO_2 emissions can no longer be viewed as simply a byproduct of a nation's GDP, but must be understood in the context of the inequality of the capitalist world-economy and the differential environmental impacts that directly result from a nation's position in the capitalist world-economy. Position in the capitalist world-economy *matters* when it comes to intensive environmental processes like CO_2 emissions.

The implication for those concerned about CO_2 emissions and climate change is that the environmental challenge the world community faces is not a problem of "mere" population or economic size (the extension of our metabolic interaction with nature), but a problem deeply embedded in the operation of the capitalist world-economy itself. Solutions to resolving the growing concern over CO_2 emissions must address the very foundation of the operation of the capitalist world-economy. The operation of the world-economy is dependent on the expansion and intensification of the use of nature, and it is evident that if focus remains limited to population and economic size issues, a significant and worrisome problem remains with respect to the intensive metabolic interaction with nature. The fundamental logic of the capitalist world-economy must be questioned and overcome to truly begin to deal with the environmental problems associated with the intensive metabolic rift that results from the intensive processes of capitalist production. The possibility for addressing climate change and other problems associated with the intensive rift may seem insurmountable, but the reality of the situation is that the operation of the capitalist world-economy cannot be disentangled from the environmental problems society faces.

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