WORLD-ECONOMY CENTRALITY AND CARBON DIOXIDE EMISSIONS: A NEW LOOK AT THE POSITION IN THE CAPITALIST WORLD-SYSTEM AND ENVIRONMENTAL POLLUTION

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ABSTRACT

With the ever-growing concern of climate change, much attention has been paid to the factors driving carbon dioxide emissions. Previous research in the World-Systems perspective has identified a relationship between carbon dioxide emissions and position in the world-economy. This study intends to build on the previous research by developing a new, more parsimonious indicator of World-System position based on Immanuel Wallerstein's theoretical concepts of incorporation and core-periphery processes. The new World-System indicator is derived from the centrality measure in network analysis based on import data from the International Monetary Fund's Direction of Trade Statistics. Based on the theoretical concepts of core-periphery processes, carbon dioxide emissions are predicted to rise based on the predominance of energy-intensive, high-technology, core processes within the nation. The results tend to demonstrate a strong relationship between carbon dioxide emissions and position in the world-economy, and the new World-System position indicator is more strongly related with carbon dioxide emissions than Gross Domestic Product per capita.

INTRODUCTION

Since the 1997 American Sociological Association – Political Economy of the World-System (PEWS) section meeting, PEWS authors addressing environmental issues (Bunker and Ciccantell 2005; Moore 2003; Prew 2003) have built on the initial contributions of Braudel (1979a; 1979b; 1979c), Wallerstein (1974; 1980; 1989) and Bunker (1985), as well other researchers who have expanded on their own and others' formulations (Burns, Kick, and Davis 2003; Grimes and Kentor 2003; Jorgenson 2003; Roberts, Grimes, and Manale 2003). Previous studies have established a connection between the position in the world-economy and their environmental impact and have added greatly to our understanding of the issue (Burns, Davis, and Kick 1997; Burns, et al. 2003; Burns, Kick, Murray, and Murray 1994; Jorgenson 2003; Jorgenson 2006; Jorgenson, Rice, and Crowe 2005; Roberts 1996; Roberts, et al. 2003; York, Rosa, and Dietz 2003). Despite the significant contributions of the above authors, room for improvement exists. Some measures of position in the world-economy have a limited numbers of cases (Arrighi and

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Drangel 1986; Kentor 2000; Mahutga 2006; Smith and White 1992), while others use composite measures that include variables such as treaties or diplomatic ties which can result in a measure with effects that can be unclear theoretically and empirically (Kick 1987; Rossem 1996; Snyder and Kick 1979).

I am proposing that a simpler measure could provide an increased number of cases and an effective indicator of World-System position. This paper attempts to build on the previous research by developing a parsimonious indicator of World-System position. The focus of this paper is not to test the effectiveness of the measure with previous formulations[1], but to outline the theoretical underpinnings of the measure and test it against an issue of contemporary concern, carbon dioxide emissions. To create this new variable, I return to certain fundamental concepts of Immanuel Wallerstein, incorporation (Hopkins and Wallerstein 1987; Wallerstein 1982) and the distinction of core and periphery processes (Wallerstein 2004).

With the introduction of this new variable, I have three fundamental research questions. First, based on the distinction of core-periphery processes, will the World-System indicator be a more effective predictor of carbon dioxide emissions than Gross Domestic Product (GDP) per capita, a variable widely used by previous researchers (Dietz and Rosa 1997; Grimes and Kentor 2003; Jorgenson 2007a; Roberts, et al. 2003)? Next, will the new World-System indicator be robust in the presence of other control variables. Lastly, will the results demonstrate a monotonic relationship between carbon dioxide emissions and the independent variables? If effective, this new, parsimonious variable of World-System position has the benefit of theoretical consistency and could replace other measures with fewer cases. This new variable has the potential to be used for new research as well as refining old models.

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. In an attempt to unravel the relationship between environmental impact and relationship within the world-economy, some World-Systems researchers focus their research on qualitative historical analysis (Barbosa 1993; Bunker 1985; Chew 1999; Dunaway 1996; Frey 1998; Moore 2000) while others use quantitative methodology (Burns, et al. 1997; Burns, et al. 2003; Burns, et al. 1994; Jorgenson 2003; Jorgenson, et al. 2005). Each has expanded our understanding of the issues involved, but I will focus on the quantitative literature.

A number of quantitative studies have already made significant contributions to understanding the impact of World-System position on environmental variables (Burns, et al. 1997; Burns, et al. 2003; Burns, et al. 1994; Jorgenson 2003; Jorgenson, et al. 2005). Many of these studies are based on operationalizations from previous authors (discussed below). Previous studies use a wide variety of operationalizations for World-System position indicators, suggesting a single commonly accepted operationalization among World-Systems analysts has yet to emerge. Prior to describing the quantitative work in World-Systems and the environment, I will briefly outline the various operationalizations.

[1] For summary and critical review of previous measures, see Babones (2005) and Prew (2005).

A number of researchers have created a variety of operationalizations over time. One widely employed methodology is block modeling (Kick 1987; Nemeth and Smith 1985; Rossem 1996; Smith and White 1992; Snyder and Kick 1979; Steiber 1979), using multiple variables to create the block models. Commodity classifications to determine World-System position were used by Nemeth and Smith (1985), Smith and White (1992), and Steiber (1979) based on the argument that core production tends to focus on finished goods while peripheral production is more characterized by raw material production.

Others (Kick 1987; Rossem 1996; Snyder and Kick 1979) use composite variables for use in their block models. These variables differ and generally attempt to pinpoint concepts central to the World-Systems perspective. Snyder and Kick (1979:1105) include “trade flows, military interventions, diplomatic exchanges, and conjoint treaty memberships.” Kick (1987) modifies Snyder and Kick’s (1979) analysis to include four different treaty ties, political conflict, armament transfers and military conflict. While attempting to incorporate similar issues, Rossem (1996) uses trade between nations, trade in major conventional weapons, presence of foreign troops, and presence of an embassy or commissariat as evidence of diplomatic representation.

Terlouw (1993) and Kentor (2000) used z-scores instead of block models to create their composite variables. Terlouw (1993) uses a nation’s part in world trade, stability of trade relations, GDP per capita as part of total world GDP, military power and diplomatic ties through diplomats and embassies. Kentor (2000) critically analyzed the prior research and offered a new multi-dimensional operationalization based on three broad dimensions of the World-System: economic power, military power and global dependence.

While these prior operationalizations have provided a solid foundation for research, they do contain two significant drawbacks. First, many are missing a substantial number of nations in the world-economy. Some researchers have less than 100 nations in their analyses (Arrighi and Drangel 1986; Jorgenson 2003; Mahutga 2006; Nemeth and Smith 1985; Smith and White 1992). Second, composite indicators of World-System position contain a number of variables that may reduce the total number of nations that may be included (Kentor 2000; Kick 1987), but also contain variables such as treaty membership and diplomatic ties (Kick 1987; Rossem 1996) that are difficult to support theoretically. The core of Wallerstein’s (2004) description of the World-System revolves around the exploitation of the periphery through unequal exchange. Economically, core processes maintain an advantage over periphery processes, while the state can be used to protect quasi-monopolies and the advantage of core processes. The role of diplomatic relations or sociocultural ties in this process is unclear.

According to Kick (1987:134), sociocultural and other diplomatic ties provide core nations with access necessary to dominate and socialize the periphery nation into their subordinate role. Rossem (1996:512) argues that “Small or poor countries … tend to establish embassies in countries that are politically most important to them.” According to Rossem (1996:512), embassies represent the nation’s importance in the World-System. While many diplomatic ties in core nations may indicate power and influence, the presence of many diplomatic ties in a peripheral nation may indicate dependence and unequal exchange with core nations. Higher numbers of diplomatic ties may produce contradictory indications of coreness or dependence depending on whether the nation is core or periphery. Periphery nations with few diplomatic relations may be more external to the system of exploitation or it may represent a concentration of dependence on very few nations. Because the effects of diplomatic or sociocultural relations may not vary monotonically, their inclusion in a composite variable may muddy the variable's effectiveness. Testing for diplomatic or sociocultural ties separately may be more illuminating than including them in a composite variable. For these reasons, I will avoid constructing a composite variable and will look for a data set that will maximize the number of nations that may be included.

In the quantitative literature of World-System and environment, researchers use a variety of operationalizations including those above as well as new formulations. Focusing on deforestation, Burns et al. (1994), uses Kick's (1984) operationalization. Burns, et al. (1997), an analysis of greenhouse gases, and Burns, et al. (2003), also addressing deforestation, use Kick (1987). Roberts' (1996) analysis of treaty participation and Roberts, Grimes and Manale's (2003) study of carbon dioxide emissions both use a modified version of Terlouw (1992). Two others investigate the impact of World-System position and its impact on a nation's ecological footprint. Jorgenson (2003) follows Kentor (2000) while York, et al. (2003) construct a new operationalization based on dependence on foreign aid.

While there have been a number of studies of carbon dioxide emissions, they have generated varying results using different methodologies. Burns, et al (1997) and Roberts, et al. (2003) specifically address carbon dioxide emissions and World-System position, while Grimes and Kentor (2003) and Jorgenson (2007a) target foreign capital penetration. Burns, et al. (1997:442) argue that carbon dioxide production is monotonically related with position in the world-economy and state that core nations "set production and consumption strategies that aggravate . . . production of industrial carbon dioxide" allowing them a greater ability to produce greenhouse gases. Two studies that focused solely on less developed countries, Grimes and Kentor (2003) and Jorgenson (2007a), found that foreign capital penetration is positively related with growth in carbon dioxide emissions.

At least three studies (Dietz and Rosa 1997; Roberts and Grimes 1997; Roberts, et al. 2003) argue against carbon dioxide emissions varying monotonically with affluence or position in the world-economy. Dietz and Rosa (1997) argue that nations exceeding $10,000 in per capita GDP experience a decline in carbon dioxide emissions resulting from affluence. They suggest that the decline is the result of a shift to a service-based economy and investment in more efficient technology.

In another study of carbon dioxide emissions, Roberts and Grimes (1997) specifically address what is referred to as the "environmental Kuznets curve." The environmental Kuznets curve suggests that rising national wealth would lead to declining environmental impacts (Grimes and Kentor 2003:265-267). Roberts and Grimes (1997) use a slightly different dependent variable than Dietz and Rosa (1997). Instead of carbon dioxide emissions as in Dietz and Rosa (1997), they use carbon dioxide intensity, carbon dioxide per unit of GDP. Even though they discover an inverted U-curve in carbon dioxide emissions, they argue that it is not the result of nations progressing through stages of development as the environmental Kuznets curve would suggest, but rather from "a relatively small number of wealthy ones becoming more efficient since 1970 while the average for the rest of the world worsens" (Roberts and Grimes 1997:196). Roberts, Grimes and Manale (2003) expand on Roberts and Grimes (1997) but tended to find similar results with respect to the inverted U-curve in carbon dioxide emissions. Based on the hypothesis that high technology in the core allows polluting industries to shift to the periphery, Roberts, Grimes and Manale (2003) found a non-linear relationship between GDP per capita and carbon dioxide emissions per GDP, as well as a non-linear relationship between their composite world-economy position indicator and carbon dioxide emissions per GDP. They argue the upward part of the slope was associated more with the world-economy indicator, while the downward slope was most clearly associated with GDP per capita (Roberts, Grimes and Manale 2003:295, 302). Roberts, Grimes and Manale (2003) also state that the results demonstrate a wide variation in the carbon dioxide emissions of semiperiphery and upper periphery.

These studies tend to demonstrate two outcomes. First, foreign capital penetration and World-System position appear to be monotonically related to carbon dioxide emissions (Burns, et al. 1997; Grimes and Kentor 2003; Jorgenson 2007a). Second, GDP per capita, when the squared term is included (Dietz and Rosa 1997; Roberts and Grimes 1997; Roberts, et al. 2003), tends to demonstrate a curvilinear relationship with carbon dioxide emissions. Of the above studies, only two (Burns, et al.1997; Roberts, Grimes and Manale 2003) specifically use a World-System indicator, and only one (Roberts, Grimes and Manale 2003) compares a World-System indicator to GDP per capita. This paper will attempt to make the direct comparison between GDP per capita squared and the new World-System position indicator to see if the results are similar.

So, what are we to gather from these different studies of environment and World-System position? The methodologies and results vary, and the variables used to indicate World-System position are not consistent. A consensus tends to exist that higher World-System position is positively related with environmental degradation, but many studies contain fewer than one hundred nations. Because many nations are missing from most of the analyses, it may be helpful to see if relationship holds with more nations included. Likewise, composite variables tend to include both economic and political variables, which may make it difficult to determine the specific relationship between the composite variable and the dependent variable. What effects would economic and political variables demonstrate when tested separately from the composite variable? For these reasons, I think it is necessary to reevaluate how we define the World-System in quantitative literature and develop a new, more parsimonious variable to represent World-System position. An indicator based on a single variable will be more conceptually clear and benefit from the inclusion of more nations.

OPERATIONALIZATION OF WORLD-ECONOMY POSITION

Beginning with the basic theoretical concepts outlined by Wallerstein (2004), it is possible to create a new operationalization of World-System position. 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 that 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 (Wallerstein 2004:28). The historical development of the capitalist world-economy did not occur instantaneously, but proceeded over time through the process of incorporation. Incorporation has both extensive and intensive components. Extensive incorporation refers to the actual geographic inclusion of external regions in the capitalist relational processes, while intensive incorporation refers to the intensification of the inequality in the capitalist relational processes (Wallerstein 1982:98-99).

Developing empirical indicators of the axial division of labor is very difficult. As mentioned above, a number of authors (Mahutga 2006; Nemeth and Smith 1985; Smith and

White 1992; Steiber 1979) attempt to create an indicator of World-System position, but they tend to focus on finished goods and raw materials. Wallerstein (2004) argues it is not necessarily the type of production or level of industrialization *per se*, but *core processes* that migrate from the core to the periphery. The actual industrial processes may, in fact, be exactly the same, but they become *peripheral processes* as they are replaced with more advanced technology in the core (Wallerstein 2004:29). Core processes include high wage, high technology, quasi monopolies, while peripheral processes are much more competitive, pay lower wages and tend to have a lower rate of profit for the immediate producer (Wallerstein 1976b:462; Wallerstein 2004:28). 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 that defines it as a core process.

In this way, core processes are those processes that are at the forefront of technology and relations of production to maintain their high profit status. Constant innovation is necessary to maintain core position by ongoing expansion of accumulation. Accumulation under capitalism demands an interaction with nature, and this interaction with nature, according to Marx (1981a:431), occurs both extensively and intensively (Prew 2003:209). Extensive expansion deals with the incorporation of ever more elements of nature. As Marx (1981b:214) explains, "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 material." Extension is simply bringing more of nature into use and can be associated with growth in general, either economic growth like GDP or population growth. Put simply, more money and/or more people equal greater consumption of nature.

Intensive use of nature is slightly different in that it speeds up the processes of nature to shorten idle capital. Marx (1981a: 213-214; 1981b:316-317) argued that natural processes like harvesting timber pose problems for accumulation because the labor process is interrupted as the tree matures. Capitalists will attempt to reduce this idle time by speeding up the natural processes. "In so far as this time of production over and above the labor time is not determined by natural laws given once and for all, as with the ripening of corn, the growth of an oak, etc., 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 process" (Marx 1981a:317).

Intensifying the processes of nature can be directly tied to the core processes described by Wallerstein (2004). High technology processes in the core are designed specifically to increase the rate of profit to further economic expansion by increasing production efficiency. By substituting human labor with energy intensive machines, the speed of production lines can be increased. Technology is substituted for natural processes. For example, bioengineered crops require fossil fuel inputs such as fertilizers, pesticides, herbicides, farm machinery, etc. in an effort to achieve greater yields from the crops. While the claims of increased yields may be dubious (Fernandez-Cornejo and Caswell 2006:9), the real point is to expand accumulation by innovating productive forces and relations. High technology core processes would tend to be very energy intensive to maintain this rate of production and would be associated with the use of natural resources used in energy production, including carbon dioxide emitting resources like natural gas, oil and coal.

Ecological Modernization (Mol 1997) argues that production in the core, being more technologically advanced, would be more efficient and therefore less environmentally unsound than production elsewhere. Although 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). This is the crux of what is known as Jevons' Paradox. Stanley Jevons argued that efficiency of production methods did not reduce the use of a certain resource like coal; it actually would increase its use. "Here, Jevons argued that increased efficiency in using a natural resource, such as coal, only generated increased demand for that resource, not decreased demand as one might expect. This was because improvement in efficiency led to further economic expansion" (Clark and Foster 2001:95). The existence of high technology and quasi-monopolies characteristic of core processes are a necessity to facilitate economic expansion and core dominance, but result in the more intensive use of nature's products.

Unfortunately, very little global data deals specifically with core processes that include high wage, high technology, quasi monopolies, etc. (Wallerstein 1976b:462; Wallerstein 2004:28). 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, making cross-national comparisons difficult. 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. This is especially true given that core processes change over time and may exist as both a core and a peripheral process at the same time depending on the economic and geographic conditions under which the production process occurs, as I discussed above.

Tracking the indicators of unequal exchange is equally difficult. Defining unequal exchange itself has proved difficult empirically, while the actual data are elusive. Recent research (Jorgenson 2006; Rice 2007) and a special issue of the *International Journal of Comparative Sociology* (Volume 50, No. 3-4, 2009) have returned to this topic with its origins in Arghiri Emmanuel (1972) and Stephan Bunker (1984). For Wallerstein (2004:28), 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 at least 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 to unequal exchange.

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

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 (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. A historical analysis of each nation's incorporation into the world-economy would be helpful to understand how a nation was incorporated, but it is not easily undertaken. Another possible method to operationalize incorporation is to attempt to locate a nations' position in the world-economy through the network of world trade. A number of researchers (Clark 2008; Clark and Beckfield 2009; Kentor 2000; Kick 1987; Kim and Shin 2002; Prew 2005; Rossem 1996) have included world-trade in their measures or created world trade position variables.

However, 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 *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 the 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, I must acknowledge 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 nor replace historical comparative research, 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, only a few use the value of trade (Prew 2005; Su 2002) while others use mere ties between nations with respect to trade (Clark 2008; Clark and Beckfield 2009; Kick 1987; Kim and Shin 2002; Rossem 1996). 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 with another 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. Su (2002:359) uses degree centrality network analysis 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 (2004). 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 uses 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 that, hopefully, addresses some of Hopkins' (1982) concerns. 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. The trade network variable 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). By using one dataset, the variable is more transparent than composite variables and retains more nations than most variables mentioned above.

In the IMF DOTS, imports and exports representing the trade between nations in millions of US dollars are listed for each included nation. Total volume of trade, imports and exports, is necessary to represent the combined role trade played in the relations of unequal exchange in the world-economy. Unfortunately, import and export data are compiled differently and are not necessarily equivalent due to 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. Because some nations are significant importers with relatively less exports and vice versa, it is important to get a measure of overall trade relationships. Focusing on imports or exports can lead to very different results. To smooth out the differences between importers and exporters in the world-economy, the imports are added to the exports. 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, eight nations (Afghanistan, Botswana, Eritrea, Laos, Mongolia, Namibia, Nepal, North Korea) are missing compared to the dependent variable, Carbon Dioxide Emissions (defined below). Carbon Dioxide Emissions is missing Somalia compared to the IMF DOTS data.

The IMF DOTS trade matrix is imported into the UCINET 6 network program (Borgatti, Everett, and Freeman 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. The symmetrical matrix resulted in a better theoretical fit with Wallerstein (1976b, 2004) than an asymmetrical matrix producing both indegree (imports) and outdegree (exports) centrality. 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).

While there are a number of possible network measures to devise a measure of World-System position, Freeman Degree Centrality tends to be the most consistent with the World-Systems Perspective. When choosing between network procedures, I found most network analysis procedures tend to produce results that lack face validity when comparing them to

World-Systems theoretical models such as Wallerstein (1976b, 2004). Some measures would appear to be better suited for World-Systems analysis, such as the Core/Periphery function. One major issue with the Core/Periphery function, or "coreness" is that it weights the coreness of an actor by the coreness of their neighboring actors in the network. Thus, Canada and Mexico, because of their relationship with the United States, tend to be positioned higher in the network than Germany and the United Kingdom when using valued data. Using simple ties, the United States falls behind a number of nations in the output. The reason the output tends not to fit theoretical models is the strength of the trading partner determines, to a degree, the position of the nation in the world-economy. While this may be true of the banking industry (Scott 1991:101), it is not the main focus of the World-Systems perspective. Core World-System position is not determined primarily by trade relationships with powerful nations, but by historical unequal exchange with peripheral regions. Eigenvector centrality has a similar problem, weighting nearby actors by calculating the "distance" from the central actors. Those in close geographic proximity to a central actor/nation tend also to be weighted more heavily because of their subsequent close trade relationship with the central actor. Bonacich Power, another measure of centrality adds an "alpha" component to the Freeman Centrality measure, but this alpha is difficult to approximate and allowing UCINET 6 to calculate it produces nonsensical results. Core nations tend to be situated in the middle, while periphery nations occupy the top and bottom of the list of nations in the output.

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 Freeman 1992:82). Therefore, the number of connections is important as well as the weight of the interaction between actors. Import/export trade volume with trading partners increases the value of the actor's centrality measure. In general, nations whose trade volume is low with other nations will have lower centrality scores than nations with 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 as a result of the axial division of labor, 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 a sizeable portion of trade volume, the fundamental relationship of inequality continues between the core and periphery nations. Centrality in the network would indicate the coreness of the nation and the presence of core processes. Nations with a low volume of trade and few ties can be understood as an indication of the subordinate role in the world-economy and a reliance on peripheral processes.

RESEARCH QUESTIONS

I wish to test three fundamental questions in this paper. First, will World-Economy Centrality be a better predictor of carbon dioxide emissions than GDP per capita? World-Economy Centrality should have strong correlation with the outcomes of the operation of the World-System such as GDP per capita, but the effects of World-Economy Centrality will be separate of GDP per capita with respect to carbon dioxide emissions. Because World-Economy Centrality is related to core processes, we would expect that it would be more closely related to carbon dioxide emissions, an intensive process, than GDP per capita, which would measure more extensive processes.

Second, will World-Economy Centrality be strongly predictive of carbon dioxide emissions and remain robust even in the presence of a number of control variables? To be a strong candidate for a new indicator of World-System position, World-Economy Centrality must be strong and consistent in a variety of models with similar variables. Aside from GDP per capita and population, a number of control variables will be included that deal with urbanization, militarism, inequality and foreign direct investment. Again, it is expected that many of these variables should be strongly correlated with, if not caused by, World-System position. Will World-Economy Centrality remain robust with the inclusion of the control variables?

Third, will World-Economy Centrality vary monotonically with carbon dioxide emissions? While previous research suggests a conflicting relationship between economic development, position in the World-System and carbon dioxide emissions (Burns, et al. 1997; Grimes and Kentor 2003; Roberts, et al. 2003), I argue that carbon dioxide emissions will vary monotonically with the centrality of the nation in the capitalist world-economy. Clark and Foster (2001) point to Stanley Jevons' argument in "The Coal Question" as grounds to question the assumption that greater efficiency in the techniques of production will lead to decreased use of natural resources. The concentration of core nations on core processes will tend to lead to more intensive energy use and higher carbon dioxide emissions. For these reasons, I predict that centrality in the world-economy will be directly related to production of carbon dioxide.

VARIABLES USED IN THE ANALYSIS

All variables in the analysis are from 1999 with the exception of the lagged carbon dioxide emissions from 1990 and the inequality variable GINI, explained below. With the exception of the World-Economy Centrality variable and FDI Inward Stock, described below, all variables are from the World Bank World Development Indicators (WDI) dataset[2] (World Bank 2001). The dependent variable, Carbon Dioxide Emissions (CO2 Emissions), is logged. In addition to the World-Economy Centrality variable, two other independent variables are significant to the analysis. First, the assumption of the IPAT model suggests that population contributes to environmental degradation. York et al. (2003) supports the idea of population as a significant contributor to environmental impact. The more people a nation has, the greater the environmental impact. Population from the World Bank WDI database (World Bank 2001) is logged and shall be included in all models. Because GDP per capita should be less associated with intensive processes, GDP per capita PPP will be used to provide a comparison to World-Economy Centrality. Both GDP per capita PPP and World-Economy Centrality are logged. To conduct a panel analysis, a lagged version of carbon dioxide emissions from 1990 is included and logged.

To test the effectiveness of the World-Economy Centrality variable, other control variables are included. To give an estimate of foreign capital penetration, Foreign Direct Investment (FDI inward stocks for the year 1999) from the United Nations Conference on Trade and Development FDI Database (United Nations Conference on Trade and Development 2005) is

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[2] To update the previous research to a panel analysis, I added carbon dioxide emissions from 1990 to the dataset from the "Quick Query selected from World Development Indicators" (World Bank 2009).

included and logged. A measure of a nation's inequality, GINI is taken from the World Bank's WDI (World Bank 2001), but the indicator is not available for all nations in 1999. To maximize the number of nations included, the GINI indicator was compiled from the WDI data set years 1985-2002. The GINI measure is logged. The World Bank's WDI (World Bank 2001) provides a specific variable for arms exports. Arms Exports (% of total exports) will be included as a measure of the development of the military within the nation. Finally, a measure of urbanization is included as Urban Population (% of total). Descriptive statistics for included variables can be found in Table 1.

Table 1. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
CO2 emissions (kt) (LN)	144	4.795	15.519	9.784	2.24
CO2 emissions (kt) (LN) 1990	142	8.90	22.29	16.48	2.43
Population WDI (LN)	146	13.98	20.95	16.315	1.342
Urban population (% of total)	145	6.051	97.26	53.085	22.692
Arms exports (% of total exports)	142	0	22.4	0.474	2.133
GINI (LN)	121	3.2	4.26	3.657	0.252
FDI inward stock UNCTAD (LN)	146	1.472	13.775	9.328	1.359
W-E Centrality (LN)	137	4.305	14.36	9.169	2.155
GDP per capita, PPP (LN)	135	6.064	10.374	8.319	1.119
GDP Per Capita, PPP Squared	135	1.85E+05	1.03E+09	1.15E+08	2.10E+08
Valid N (listwise)	114				

REGRESSION MODELS

Panel regression will be used for all models. A panel regression model includes a lagged version of the dependent variable as an independent variable in the regression model. Because a high correlation is expected between the dependent variable and a lagged version of the dependent variable, panel regression is a very conservative test of the independent variables (Shandra, London and Williamson 2003). Because of the close correlation between carbon dioxide emissions and the World-Economy Centrality variable, it is a very strong test of the effectiveness of the explanatory power of World-Economy Centrality (see Figure 1 below). The panel regression models tested are based on the parsimonious STIRPAT model of York, et al. (2003). The STIRPAT model is described as "environmental Impacts are the multiplicative product of Population, Affluence (per capita consumption or production), and Technology (impact per unit of consumption or production)" with the inclusion of an error term (York, et al. 2003:280-281). 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.

To fully test World-Economy Centrality, eight models are conducted using Carbon Dioxide Emissions as the dependant variable on all models. The first four models will focus on World-Economy Centrality and GDP per capita PPP and hold the cases constant with 128 nations. The last four models focus on the control variables, which reduces the valid cases to

114. Model 1 will contain only the lagged Carbon Dioxide Emissions 1990, Population and World-Economy Centrality. Holding the cases constant to make a comparison, Model 2 will contain the lagged Carbon Dioxide Emissions 1990, Population and GDP per capita PPP. Model 3 includes both World-Economy Centrality and GDP per capita PPP along with the lagged Carbon Dioxide Emissions 1990 and Population for a direct comparison. Model 4 is the same as Model 3 with the inclusion of the squared component of GDP per capita PPP. The next four models all include the control variables mentioned above. Model 5 contains the control variables the lagged Carbon Dioxide Emissions 1990 and Population. Model 6 adds World-Economy Centrality, Model 7 adds both World-Economy Centrality and GDP per capita PPP, and Model 8 includes all variables.

RESULTS AND DISCUSSION

The results tend to confirm that World-Economy Centrality is a better predictor of carbon dioxide emissions than GDP per capita, and World-Economy Centrality is robust with the inclusion of a variety of variables. The results of the eight models are presented in Table 2.

Given the results of the analysis, World-Economy Centrality appears to be a strong predictor of carbon dioxide emissions and more effective than GDP per capita. In all models where it was included, World-Economy Centrality was significant at the .01 level or above and, with the exception of the lagged Carbon Dioxide Emissions from 1990, had the highest standardized coefficients in all models. Focusing on the comparison with GDP per capita PPP, World-Economy Centrality does appear to fair better overall than GDP per capita when predicting carbon dioxide emissions. The R square is slightly better for World-Economy Centrality in Model 1 (R square = .959) compared to GDP per capita PPP in Model 2 (R square = .955). When included together in Model 3, the standardized coefficient for World-Economy Centrality is more than five times GDP per capita PPP, which is non-significant. Additionally, the fit remains the same with GDP per capita PPP included in Model 3 compared to Model 1 with the lagged Carbon Dioxide Emissions 1990, Population and World-Economy Centrality.

When GDP per capita PPP and World-Economy Centrality are included together in the models, there is problematic multicollinearity according to some standards, “VIF values of 7-10 or higher” (Rice 2007:1380). While this may raise some concern, Robert O’Brien (2007) suggests that rules of thumb regarding the VIF should not automatically be applied. “The practice of automatically questioning the results of studies when the variance inflation factor is greater than 4, 10, or even 30 … [is] as inappropriate as questioning the results of studies based on sample sizes less than 200, because they do not meet ‘the rule of 200’” (O’Brien 2007:681). Nearly all cross-national studies have sample sizes lower than 200 cases, and cross-national variables like GDP, world-economy position, population, foreign direct investment, etc. are expected to be correlated theoretically. The process of stratifying the world-economy into core and peripheral regions has direct theoretical links to investment, economic size and demographic trends. Specifically, this paper is attempting to tease out the theoretical effects of two highly correlated variables. O’Brien (2007:683) argues shifting the model to reduce multicollinearity may mean that the theory being tested also changes. Attempts to further reduce the multicollinearity would compromise the theoretical questions being posed by this study. Many of the relevant variables could be per-capitized, but the individual effect of population would disappear from the analysis, however it is crucial to the IPAT conceptualization. The major overlaps are between the dependent variable, World-Economy Centrality and GDP per capita, which are the variables of most importance to the theoretical questions being asked. For these reasons, I acknowledge the higher VIFs in some models, but have not attempted to completely eliminate multicollinearity because doing so may compromise the theoretical model.

The better fit of World-Economy Centrality is graphically represented by the scatterplots in Figures 1 and 2. The scatterplot of World-Economy Centrality with Carbon Dioxide Emissions tends to be more narrow and linear than GDP per capita and Carbon Dioxide Emissions. The better fit, both in the regression models and graphically, is consistent with the predicted relationship between World-Economy Centrality associated with core processes and energy intensive processes such as carbon dioxide emissions. GDP per capita is expected to deal more with extensive processes that incorporate more of nature into production and consumption rather than specifically intensifying production processes as in World-Economy Centrality. By identifying core processes, World-Economy Centrality may represent a unique variable that will act differently than other World-System indicators in other analyses. Perhaps a new avenue of research could contrast previous conceptualizations of World-System indicators and the new World-Economy Centrality.

With respect to the inclusion of control variables, World-Economy Centrality tends to be robust when multiple variables are included in the model. For comparative purposes by holding the cases constant, Model 5 with only the control variables does not improve the fit over a model with World-Economy Centrality, the lagged Carbon Dioxide Emissions 1990 and Population (model not included in Table 2). Holding the cases constant, the R square for World-Economy Centrality, the lagged Carbon Dioxide Emissions 1990 and Population is .961 compared to .953 in Model 5. When included, World-Economy Centrality remains significant and has the second largest standardized coefficients behind the lagged Carbon Dioxide Emissions 1990 in all of the models. Despite the inclusion of control variables, World-Economy Centrality retains its significance and relative strength in the equation. Alternatively, the control variables do not tend to have consistent results in the various models.

Some of the control variables have strong, significant results. Urban Population is positively related to Carbon Dioxide Emissions when World-Economy Centrality is excluded, but its effect diminishes as other variables are included. Urban population could be associated with more fossil fuel use, but once World-Economy Centrality is included, the effect of core processes takes precedence over urban environments. This would suggest that it is not just simply urbanization, but urbanization that includes core processes that drives carbon dioxide emissions. Arms Exports are also significant in the full model when included, but not in other models. This would tend to suggest that military industry may be minimally associated with activities that produce carbon dioxide emissions. Foreign Direct Investment is significant in Model 6 and 7 but opposite of the expected direction. The effects of foreign direct investment may vary by region of the world-economy and lead to different levels of carbon dioxide. In core nations, it may produce high technology, energy intensive, core processes, while in the periphery it may produce agricultural production or, more accurately, periphery processes. Once world-economy position is taken into account through World-Economy Centrality, foreign direct investment may lead to production processes in the periphery that tend to be more peripheral in nature. Foreign direct investment is a complex variable especially since it may actually follow economic growth instead of promoting it (Babones 2009). The measure of inequality, GINI, is not significant in any of the models where it was included.

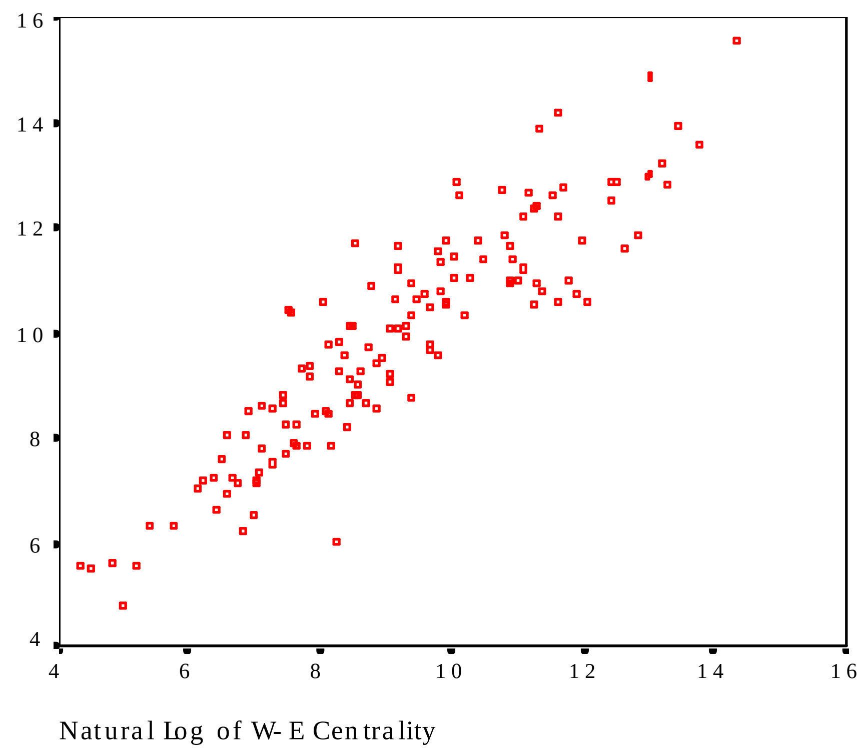
Table 2. Standardized Regression Coefficients for Carbon Dioxide Emissions: 128 nations circa 1999

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
N	128	128	128	128	114	114	114	114
R square	.959	.955	.959	.964	.953	.967	.968	.970
CO2 Emissions 1990 (LN)	.641*** (4.830)	.680*** (4.503)	.634*** (4.977)	.590*** (5.392)	.706*** (4.530)	.586*** (5.570)	.578*** (5.614)	.550*** (6.182)
Population (LN)	.098*** (1.527)	.231*** (2.470)	.127** (4.879)	.130** (4.881)	.217*** (2.993)	.163*** (3.207)	.230*** (6.394)	.215*** (6.566)
W-E Centrality (LN)	.304*** (4.415)		.252*** (14.390)	.309*** (15.070)		.368*** (9.810)	.260** (18.023)	.271*** (18.118)
GDP per capita PPP (LN)		.222*** (2.956)	.050 (9.633)	.119* (10.627)			.129* (11.634)	.155* (12.135)
FDI Inward Stock UNCTAD (LN)					.044 (2.868)	-.112** (4.617)	-.127** (4.782)	-.067 (7.404)
Arms Exports (% of total exports)					.012 (1.123)	.033 (1.154)	.030 (1.157)	.038* (1.201)
Urban Population (% of total)					.154*** (2.911)	.073* (3.394)	.056 (3.575)	.048 (3.629)
GINI (LN)					-.005 (1.308)	.029 (1.391)	.037 (1.432)	.019 (1.662)
GDP per capita PPP Squared				-.111*** (2.639)				-.079* (4.512)

*$p < .05$ **$p < .01$ ***$p < .001$
VIF Collinearity Statistics in parentheses

In general, the first two research questions tend to be supported. World-Economy Centrality tends to perform better than GDP per capita PPP, and World-Economy Centrality is robust with the inclusion of control variables. The final research question is a little more complex. In Model 4 and Model 8, GDP per capita PPP squared is significant but has the lowest, or next to lowest, standardized coefficients of the significant variables[3]. As Dietz and Rosa (1997), Roberts and Grimes (1997) and Roberts, Grimes and Manale (2003) suggest, GDP per capita squared does show a negative relationship with Carbon Dioxide Emissions. Roberts and Grimes (1997) suggest it is because some nations in the core are improving their efficiency while the periphery and semiperiphery are increasing their rate of emissions. While this argument may be accurate, the negative relationship of GDP per capita squared and carbon dioxide emissions may also be due to what GDP per capita actually measures. World-Economy Centrality measures the position in the world trade network. GDP per capita measures the average economic output per person in a nation.

Figure 1. Scatterplot of Carbon Dioxide Emissions (LN) by World-Economy Centrality (LN)



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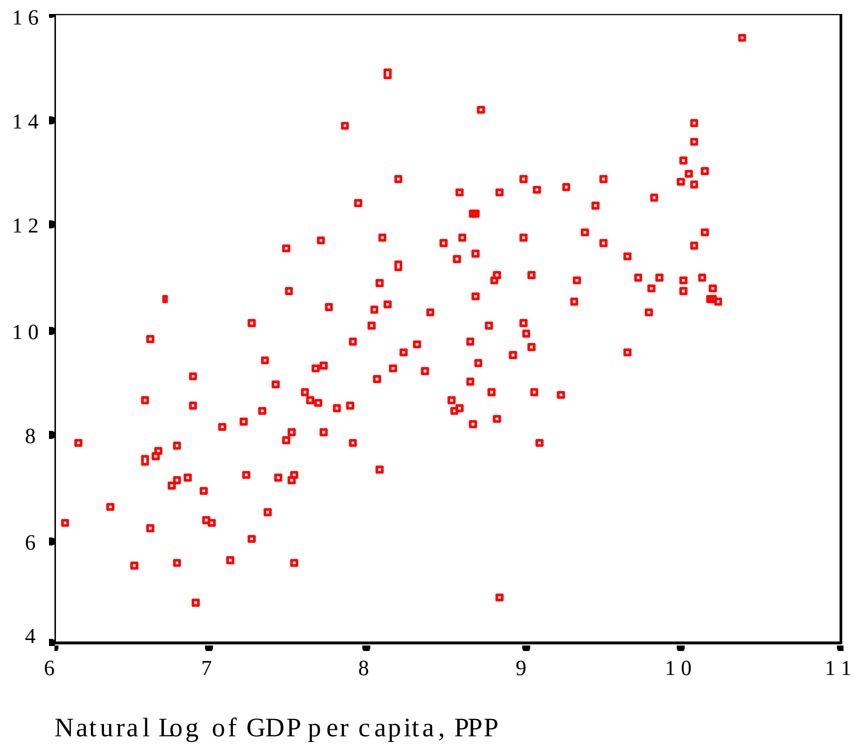
[3] In models (not shown in Table 2) where population was excluded and carbon dioxide emissions as well as World-Economy Centrality were percapitized, the relationship remained exactly the same between the included variables and GDP per capita squared.

Figure 2. Scatterplot of Carbon Dioxide Emissions (LN) by GDP per capita PPP (LN)



The distinction between what the two variables actually measure is important for understanding why a so-called environmental Kuznets curve may be found. GDP per capita is defined in a variety of ways: "economic development" (Jorgenson 2007b:842; Kick, et al. 2000:141; York, et al. 2003:288), a "country's wealth" (Grimes and Kentor 2003:269; Roberts, et al. 2003:282), "affluence" (Dietz and Rosa 1997:177; York, et al. 2005:141) or "capital intensiveness" (Kentor 2000:35-36). The range of definitions reflects the lack of conceptual clarity and theoretical grounding in its use. While dividing GDP by the number of people in a nation may seem straightforward, the reasons for nations to have varied populations and economic output are not. The ordering of nations by GDP per capita may result from a range of conflicting historical and geographic realities. Nations vary in geographic topography and size, allowing for more or less population. The geographic differences are compounded by the operation of the world-economy and the historical relationships between nations. As a result of the operation of the capitalist world-economy, many nations have been prevented from proceeding through the demographic transition (Foster 1994), resulting in high population growth. Even with nations of roughly similar GDP per capita, a variety of historical factors may be at work. The average economic output per person may result from social-democratic redistributive practices (Sweden), a high degree of wealth generation coupled with high inequality (South Africa), a confined geographic space with a relatively homogenous standard of living (Slovenia), a well-developed commercial/industrial sector combined with an extensive internal periphery (Canada), etc. In this way, GDP per capita organizes nations in a way that is not easily discernable conceptually. A cursory look at the list of nations by GDP per capita reveals that it is not quite clear exactly what GDP per capita is measuring.

The Appendix compares World-Economy Centrality, GDP per capita PPP and Carbon Dioxide Emissions. In the list of nations for GDP per capita PPP, social-democratic European nations tend to be at the top with some of the largest economies in the world, but the most powerful core nations are excluded from the very top except for the presence of the United States. The European nations tend to be followed by Eastern European nations. It is not until the middle of the list of nations that nations like China, India and Indonesia appear. In this way, GDP per capita tends to disproportionately place more equitable nations with smaller economies at the top of the hierarchy. For example, of the top twenty-five emitters of carbon dioxide, China, Russia, India, Mexico, Brazil, and Thailand all fall well below the top twenty-five in GDP per capita. Many of these nations tend to be powerful, regional, economic actors. Compared to World-Economy Centrality, seven nations are included in the top twenty-five nations in GDP per capita that are not in the top twenty-five emitters of carbon dioxide: Greece, Israel, Portugal, Kuwait, Norway, New Zealand and Slovenia. It is difficult to find a coherent conceptual framework that would explain the close proximity of nations as diverse as Kuwait, Norway, Slovenia and New Zealand, or why nations like Ireland and Canada should be ranked higher than Germany and Japan. In contrast to the definitions used above, the order of nations in the hierarchy of GDP per capita is not necessarily by wealth, degree of affluence, level of economic development, penetration of industrial or post-industrial processes, etc.

What social forces lead the nations to be organized in this fashion? Unfortunately, GDP per capita does not capture a single, clear, causal mechanism, but incorporates many intertwined and contradictory influences. As a result of dividing economic output by the number of people in the nation, GDP per capita places European social-democratic nations at the top and very large emerging economies in the middle. This arrangement of nations would tend to demonstrate a curvilinear relationship with carbon dioxide emissions, but it is not the result of a specific, identifiable, causal mechanism. It is a statistical artifact of how the variable, GDP per capita, orders nations in the world-economy.

In summary with respect to the third research question, carbon dioxide emissions vary monotonically with position in the world trade network, World-Economy Centrality. I would argue that this relationship is found because the largest and most core economies tend to fall in a consistent hierarchy in the World-Economy Centrality variable. In general, the Jevons' paradox appears to be supported. As Jevons' paradox would suggest, there are no efficiency gains with more efficient technology associated with core processes. Those nations pursuing expanded accumulation, especially using core processes, continue to be those that produce the most carbon dioxide emissions.

In contrast, carbon dioxide emissions demonstrate a curvilinear relationship with GDP per capita. It is difficult to propose a clear relationship between carbon dioxide and GDP per capita, but it appears as though nations that tend to emphasize social-democratic governance and/or have successfully proceeded through the demographic transition have an advantage in reducing carbon dioxide emissions. While not exactly commensurable because of the differing definitions of core nations, this assertion tends to be supported by Roberts and Grimes (1997) argument that some core nations are improving carbon dioxide emission efficiency while periphery nations' efficiency is worsening. In effect, nations are not improving their environmental efficiency as they "progress," but nations who have successfully proceeded through the demographic transition and developed strong social-democratic governance structures may be improving their rate of emissions while powerful economies expand emissions, and nations trapped below them also see their emissions worsen.

While this may be the case, the question still remains whether the ordering of nations by GDP per capita is what is meant by the environmental Kuznets curve. Would the smaller social-democratic nations like Norway, Denmark, and Netherlands be considered more affluent than the much larger economies of Japan, Germany, France, etc? Likewise, would Slovenia, the Czech Republic, Hungary and Costa Rica be considered more economically developed than China, India, Russia, Mexico, Brazil, etc? If not, then there is little support for the concept of the environmental Kuznets curve as well as possibly calling into question the application of GDP per capita in general.

CONCLUDING REMARKS

This paper focused on three fundamental research questions. Would World-Economy Centrality be a better predictor of carbon dioxide emissions than GDP per capita? Would World-Economy Centrality be robust in a variety of models with a number of control variables? Is there a curvilinear relationship between carbon dioxide emissions and World-Economy Centrality? To answer these questions, it was necessary to develop a new indicator of World-System Position to deal with a number of weaknesses in the previous indicators. The World-Economy Centrality variable includes many more nations than most other indicators, partially because it is not constructed as a composite variable. World-Economy Centrality has other advantages over composite variables. In the results, the variable indicating military development varied in strength and significance depending on the model. Foreign Direct Investment was significant in an unexpected direction. While this analysis analyzed carbon dioxide emissions, perhaps each of these variables may have stronger or weaker relationships with different dependent variables. If these variables were included in a composite variable, their varying effects would not be known.

The parsimony of the World-Economy Centrality variable allows for clear and direct ties to theory. World-Economy Centrality is designed to be associated with core processes in the world-economy by focusing on the incorporation of a nation in the network of world trade. Not only are the number of ties used, but also the strength of those ties as indicated by a combination of imports and exports. This simple design is not only clear in conception, the resultant hierarchy of nations is consistent with the theory from which it originates (Wallerstein 1976b; Wallerstein 2004). The theoretical ties to core processes may be directly responsible for the usefulness of World-Economy Centrality to explain carbon dioxide emissions.

The World-Economy Centrality variable appears to successfully address the research questions. World-Economy Centrality tends to better explain carbon dioxide emissions than GDP per capita and is robust with the inclusion of multiple control variables. In fact, World-Economy Centrality explained more variance than all of the control variables (when included in models with the lagged Carbon Dioxide Emissions 1990 and Population).

The question of whether carbon dioxide emissions vary monotonically with position in the world-economy is more complex. It is clear that there is a monotonic relationship with World-Economy Centrality, but there is still a curvilinear relationship with GDP per capita. While Roberts and Grimes (1997) raise serious doubts about the environmental Kuznets curve, I still question what GDP per capita is measuring. While the relationship may be curvilinear, what does it really mean with respect to GDP per capita? GDP per capita creates distortions in how nations are ordered in the world-economy. Nations with large GDP's and large populations (i.e. China and India) are devalued in the world-economy relative to nations with similar or lower GDP's with much lower populations. Social-democratic nations tend to occupy the top echelon in GDP per capita, while emerging economies with large populations are relegated to the middle. Their impact in the world-economy is not lessened by a larger population, nor does it change that fact that there is a significant amount of productive activity within the nation. Perhaps the use of GDP per capita needs to be rethought to define exactly what is being measured.

The ability of World-Economy Centrality to better identify the impacts of core processes has direct implications for the STIRPAT model outlined by York, et al. (2003). The STIRPAT model is described as "environmental Impacts are the multiplicative product of Population, Affluence (per capita consumption or production), and Technology (impact per unit of consumption or production)" with the inclusion of an error term (York, et al. 2003:280-281). While population plays a very clear role in the equation and GDP per capita is meant to be representative of affluence, technology is usually considered part of the error term (York, et al. 2003:281). World-Economy Centrality is distinct from GDP per capita in that it includes technology as well as affluence by focusing on position in the world-economy and subsequently, the predominance of core processes. Given this distinction between core and periphery processes, new research could attempt to contrast World-Economy Centrality with other measures more associated with extensive processes in nature. While GDP per capita poses conceptual issues, could other measures of extensive processes be contrasted with World-Economy Centrality? It may be found that each will be more useful in predicting different types of environmental impacts. Those processes that are more acutely related to technology and "intensive" use of nature (Prew 2005) will be more likely associated with World-Economy Centrality, while processes associated with sheer increased consumption will be more associated with "extensive" processes and variables like population and GDP.

The development of the World-Economy Centrality variable provides potential for new avenues of research in the area of World-Systems and the environment, as well as reevaluation of previous models. The predictive power of the World-Economy Centrality variable is surprising given the supremacy of GDP per capita in previous research. World-Economy Centrality could be used to reevaluate prior research using other World-System position indicators. Because World-Economy Centrality is constructed from a dataset collected yearly, research could expand into time-series analyses. Are changes in carbon dioxide emissions or other environmental degradation variables consistent over time with position in the World-System?

Given the focus on climate change and the production of greenhouse producing gases, centrality in the world-economy provides a new insight into the factors giving rise to this important, contemporary problem. It is not mere economic size, but the production processes utilized. Contrary to assumptions about the reduction of environmental impacts due to increased efficiency, Jevons' Paradox appears to hold when it comes to carbon dioxide emissions. Public policy cannot rely on efficiency gains to reduce our contributions to greenhouse gases, but must recognize that efficiency may only increase production of greenhouse gas pollutants. The results of this study suggest that we should think critically about focusing on the efficiency of greenhouse producing processes such as so-called "clean coal" because they will only increase the amount of greenhouse gasses in the long run. Pressures placed on so-called developing economies to increase their efficiency and reduce greenhouse gases may result in greater efficiency, but also greater production of greenhouse gases as they race to grow their economies to compete in the world-economy. The answer to the problem of greenhouse gases lies not in developing greater efficiency, but a fundamental shift in logic for our world-economy. Expansion can no longer be the driving force guiding our relationship with the earth. Since capitalism is an inherently expansionary system, we must find a new relationship with nature if we are to be sustainable into the future.

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Appendix. World-Economy Centrality and GDP per capita, PPP sorted by CO2 Emissions (Top 25 in each category are in bold)

	W-E Centrality	GDP per capita PPP	CO2 Emissions
United States	**1723821.625**	**32030**	**5495435.744**
China	**454984.563**	3370	**2825024.608**
Russian Federation	**107244.648**	6080	**1437339.568**
Japan	**708958.813**	**23890**	**1155163.936**
India	**81690.117**	2580	**1076988.832**
Germany	**975075.375**	**23620**	**792204.432**
United Kingdom	**551517.563**	**22240**	**539337.136**
Canada	**447958.031**	**25250**	**438628.432**
Italy	**431123.500**	**22780**	**422719.344**
Korea, Rep.	**248067.047**	**13200**	**393509.936**
Mexico	**269297.281**	7880	**378494.864**
Ukraine	23035.525	3590	**374306.912**
France	**581965.875**	**21860**	**359687.552**
Australia	**116706.055**	**23560**	**344445.312**
South Africa	47233.555	10430	**334581.824**
Poland	69820.773	8620	**314389.520**
Iran, Islamic Rep.	24627.186	5300	**301433.616**
Brazil	**100175.047**	6820	**300656.848**
Spain	**239808.125**	**18460**	**273667.824**
Indonesia	79127.383	2790	**235624.512**
Saudi Arabia	74756.570	12520	**235408.336**
Korea, Dem. Rep.	*-Missing-*	*-Missing-*	**208650.144**
Thailand	**109528.398**	5870	**199658.688**
Turkey	63841.840	5730	**198493.536**
Argentina	48139.895	11700	**137799.376**
Netherlands	**371387.813**	**25410**	134641.008
Venezuela, RB	32548.000	5350	125825.424
Malaysia	**153555.625**	7890	123652.672
Egypt, Arab Rep.	19628.051	3250	123586.720
Uzbekistan	4957.500	2210	116606.800
Kazakhstan	9553.851	4780	112836.544
Czech Republic	53453.359	13150	108853.776
Belgium	**302420.031**	**23570**	104438.656
Pakistan	17726.105	1760	98869.376
Algeria	22359.914	5870	90812.240
United Arab Emirates	54948.426	*-Missing-*	87976.304
Greece	34792.566	**15270**	85946.448
Romania	18283.934	5230	81205.232
Iraq	9672.900	*-Missing-*	74239.968
Philippines	63550.645	3610	73214.048

Colombia	22910.309	6680	63640.016
Chile	28784.859	8320	62515.168
Austria	**128240.102**	**24890**	61364.672
Israel	52972.723	**19080**	61126.512
Portugal	59687.145	**16450**	60001.664
Finland	**79165.117**	**22150**	58374.848
Belarus	11875.312	6600	57631.056
Hungary	52340.977	11050	56879.936
Syrian Arab Republic	6515.900	3200	53358.832
Denmark	**85086.789**	**26710**	49658.192
Kuwait	18062.697	**18180**	47969.088
Sweden	**142555.266**	**22110**	46580.432
Vietnam	14679.499	1810	46569.440
Libya	12875.432	*-Missing-*	42769.872
Bulgaria	9090.361	5850	42088.368
Switzerland	**172002.609**	**26720**	40578.800
Ireland	**106888.305**	**26230**	40413.920
Nigeria	19567.398	820	40388.272
Yugoslavia, Fed. Rep.	3151.310	*-Missing-*	39508.912
Norway	75397.781	**27810**	38710.160
Slovak Republic	20270.447	10890	38622.224
Morocco	15778.497	3340	35837.584
Azerbaijan	1857.600	2340	33628.192
Turkmenistan	1890.500	3070	32415.408
New Zealand	26776.322	**17860**	30773.936
Peru	11908.540	4410	30392.880
Bangladesh	10717.422	1430	25446.480
Cuba	4674.551	*-Missing-*	25376.864
Trinidad and Tobago	4913.330	7940	25087.408
Dominican Republic	9545.690	6340	23273.728
Ecuador	8528.300	3020	23266.400
Croatia	10983.020	8100	20789.536
Yemen, Rep.	3942.490	740	18257.712
Zimbabwe	3323.560	2700	17623.840
Tunisia	15931.300	5700	17480.944
Lebanon	6088.540	4070	16913.024
Estonia	15607.932	8330	16154.576
Jordan	4295.220	3720	14571.728
Slovenia	17891.510	**15280**	14425.168
Lithuania	7682.361	7370	13241.696
Cote d'Ivoire	7009.189	1560	12116.848
Macedonia, FYR	2581.920	5930	11376.720
Bolivia	2212.970	2230	11241.152
Angola	5444.099	2120	10270.192

Jamaica	3937.910	3460	10215.232
Guatemala	8602.200	4230	9672.960
Myanmar	2518.300	*-Missing-*	9200.304
Kenya	4713.601	980	8837.568
Sri Lanka	8569.920	3130	8647.040
Panama	5164.150	5690	8251.328
Mongolia	*-Missing-*	1650	7547.840
Latvia	5051.401	6450	6587.872
Uruguay	5328.899	8550	6547.568
Moldova	1689.100	1990	6496.272
Costa Rica	11554.600	10120	6118.880
El Salvador	5939.300	5070	5770.800
Ghana	4718.980	2060	5576.608
Ethiopia	1693.800	720	5503.328
Georgia	1247.800	2160	5375.088
Tajikistan	1427.960	980	5100.288
Honduras	7011.600	2680	5027.008
Bosnia and Herzegovina	3190.071	5290	4821.824
Kyrgyz Republic	1009.810	2460	4715.568
Cameroon	2770.440	1520	4693.584
Paraguay	3322.051	5100	4528.704
Botswana	*-Missing-*	6690	3876.512
Nicaragua	1780.900	*-Missing-*	3755.600
Senegal	2045.980	1360	3740.944
Gabon	4426.200	5730	3554.080
Nepal	*-Missing-*	1190	3319.584
Armenia	956.500	2250	3077.760
Mauritania	732.320	1840	3037.456
Sudan	1981.700	1770	2634.416
Tanzania	2061.820	470	2528.160
Mauritius	3447.190	8850	2469.536
Papua New Guinea	2427.570	2710	2425.568
Congo	1217.200	890	2403.584
Congo, Dem. Rep.	1760.300	780	2143.440
Madagascar	670.980	760	1897.952
Zambia	1457.160	720	1806.352
Albania	1163.320	3180	1513.232
Haiti	590.380	1880	1414.304
Uganda	786.430	1370	1370.336
Mozambique	505.180	960	1333.696
Togo	1114.070	1690	1326.368
Guinea	1124.730	1840	1264.080
Benin	846.420	890	1256.752
Niger	470.160	860	1135.840

Burkina Faso	719.320	1050	1014.928
Afghanistan	*-Missing-*	*-Missing-*	963.632
Malawi	625.380	570	769.440
Cambodia	1103.200	1590	674.176
Eritrea	*-Missing-*	1070	582.576
Rwanda	214.610	1100	564.256
Sierra Leone	327.290	430	542.272
Mali	907.960	740	498.304
Lao PDR	*-Missing-*	1420	406.704
Liberia	3844.659	*-Missing-*	399.376
Central African Republic	120.620	1250	267.472
Guinea-Bissau	74.050	890	260.144
Gambia, The	177.240	1860	252.816
Burundi	87.670	670	241.824
Namibia	*-Missing-*	6790	128.240
Chad	144.540	1000	120.912
Somalia	285.970	*-Missing-*	*-Missing-*
Lesotho	*-Missing-*	2160	*-Missing-*