Carbon Dioxide Emissions in Central and Eastern European Nations, 1992-2005: A Test of Ecologically Unequal Exchange Theory

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Abstract

The author engages the theory of ecologically unequal exchange to assess the extent to which growth in per capita anthropogenic carbon dioxide emissions in Central and Eastern European (CEE) nations is a function of the "vertical flow" of exports to high income nations. Initial results of cross-national fixed effects panel model estimates for 1992 to 2005 indicate that growth in such emissions in these transition economy nations is negatively associated with the vertical flow of exports, which contradicts the tested theoretical proposition. However, additional findings indicate that the effect of the vertical flow of exports on emissions have increased in magnitude through time, going from being environmentally beneficial for CEE nations to quickly becoming environmentally harmful and increasingly ecologically unequal.

Keywords: *carbon dioxide emissions, environmental sociology, international political-economy, ecologically unequal exchange, Central and Eastern Europe, transition economies, globalization*

Introduction

Comparative-international research on the human dimensions of environmental change is a growing area of theoretically rich and methodologically sound inquiry. Within this body of work, increasing attention is paid to how structural relationships between societies contribute to various forms of environmental harms, including greenhouse gas emissions, deforestation, industrial water pollution, and biodiversity loss. Besides their ecological consequences, such environmental outcomes have significant public health and broader development implications, especially for developing nations in the Global South. Further, the pursuit of ecologically sensitive development that benefits peoples of all strata is central to sustainable development discourse.

Ecologically unequal exchange is one of the emergent perspectives in this body of literature and research. Generally speaking, the theory considers how particular aspects of international trade — especially the "vertical flow" of exports — allows for high income nations to partially externalize their environmental impacts to developing nations. While the theory is rich in substance and multiple strands of research lend support to its key propositions, a serious limitation exists, which potentially challenges the generalizability of the perspective. In particular, past research in this tradition fails to examine the extent to which structural relationships between the transition economies of Central and Eastern European nations and high income nations are ecologically unequal, thus leading to increases in environmental harms in the former. This is far more than a theory testing limitation, which is itself well beyond trivial. More broadly, comparative-international research on the various human dimensions of environmental degradation in Central and Eastern Europe in the post-Soviet era is close to non-existent in the social sciences. Given the noteworthy political-economic and demographic changes taking place in these nations in recent decades, rigorous assessments of their environmental and ecological impacts would offer valuable insights for future sustainable development efforts in such places.

This study is a modest effort to help resolve the prior limitations of research in the ecologically unequal exchange tradition in particular, while also enhancing our collective understanding of the causes of environmental degradation in Central and Eastern European nations in general. To do so, and consistent with past quantitative research in the ecologically unequal exchange tradition, I employ fixed effects panel regression techniques to evaluate the extent to which the vertical flow of exports to high income nations contributes to per capita anthropogenic carbon dioxide emissions in a sample of Central and Eastern European nations from 1992 to 2005. Further, I assess the extent to which the magnitude of the effect of the vertical flow of exports on emissions has increased or decreased through time. Building on prior research and for purposes of valid statistical inference, the estimated models of per capita emissions also control for other potentially relevant factors, including levels of economic development, levels of exports, urbanization, and the relative size of non-

dependent populations.

I begin with the literature review, where I summarize the arguments of ecologically unequal exchange theory as well as past empirical assessments of the perspective. In this section I also discuss the importance in and validity of testing the theory in a study of the transition economies of the Central and Eastern European nations. Next, I describe the panel dataset, model estimation techniques, and all the variables employed in the panel analyses. Following the presentation of the findings for the panel analysis, I conclude by briefly discussing the key results of the study and their theoretical significance, and I call for other environmental social scientists to pursue future comparative research on society / nature relationships in the greatly overlooked region of Central and Eastern Europe.

Literature review

The theory of ecologically unequal exchange is largely influenced by the classic unequal exchange tradition (e.g., Emmanuelle 1972) and especially Stephen Bunker's (1984) research on how natural resource extraction shaped the underdevelopment of the Amazon in earlier decades. Bunker argued that social scientists should play closer attention to the potentially harmful environmental and human well-being impacts of export dynamics for developing countries. More specifically, he suggested that prior research had failed to adequately consider how and the extent to which the extraction and export of natural resources (and manufactured products) from developing countries involve a vertical flow of value embodied in energy and matter to high-income countries. He argued that this transfer of value influences the environmental, demographic, and structural contexts in which subsequent development efforts unfold, potentially complicating and negatively impacting the quality of life for domestic populations.

Drawing from these earlier foundational works, the theory of ecologically unequal exchange asserts that partly through the "vertical flow of exports" from developing nations, high income nations partially externalize their consumption-based environmental costs to the former, which in turn increase forms of environmental degradation and pollution within their borders while suppressing domestic levels of resource consumption, often well below globally sustainable thresholds (e.g., Hornborg 1998; Jorgenson 2006, Jorgenson and Clark 2009; Rice 2007a, 2007b). Generally speaking, the populations of high income countries are positioned advantageously in the contemporary world economy, and thus more likely to secure and maintain favorable terms of trade allowing for greater access to the natural resources and sink capacity of areas within developing nations. It is argued that these structural relationships allow for high income nations to partly outsource or shift the environmental costs and burdens of their consumption levels. This contributes to the depletion of natural resource stocks and growth in pollutants in developing nations, with some pollutants leading to local environmental disruptions while others potentially harming large as well as small ecological systems.

The use of formal comparative methods and quantitative measurements to assess key assertions of the theory has proven to be quite challenging.[2] Readily available data on trade deal primarily with relative levels of imports or exports as well as the composition of traded goods. However, the theory of ecologically unequal exchange largely focuses on the environmental impacts of the structure of international trade. In other words, it matters where natural resources and manufactured goods come from as well as their final destinations for human use and eventual disposal. As posited by the theory, the vertical flow of exports from developing nations to high income nations is a structural mechanism through which ecologically unequal exchanges occur and their environmental consequences in developing nations unfold.

Fortunately, relational measures of trade are becoming increasingly available in longitudinal form from various sources, including the International Monetary Fund (http://www2.imfstatistics.org/DOT/) and the World Bank (http://data.worldbank.org/), which allow for the assertions of ecologically exchange theory concerning the structure of international trade to be tested in quantitative comparative analyses. For example, while using such relational measures, a series of studies find that the vertical flow of exports from developing nations to relatively higher-income nations contributes to higher rates of deforestation within the borders of the former (e.g. Jorgenson 2006; Jorgenson, Austin, and Dick 2009; Shandra, Leckband, and London 2009), while related research links loss of biodiversity and organic water pollution in lower-income nations to the same structural characteristics of international trade (e.g., Shandra, Leckband, Mckinney, and London 2009; Shandra, Shor, and London 2009). Further, cross-sectional (e.g. Rice 2007a) and longitudinal studies (e.g. Jorgenson and Clark 2009) both suggest that the vertical flow of exports suppresses the resource consumption levels of populations within developing nations, often well below globally sustainable thresholds. Such relationships have public health consequences for developing countries, given the fundamental associations between resource consumption and well-being for their populations (see also Dietz, Rosa, and York 2009), and the longitudinal analyses indicate that the magnitude of the relationship has grown through time, suggesting that these structural relationships have become increasingly ecologically unequal.

Other forms of environmental harms possibly resulting

from ecologically unequal relationships could include anthropogenic greenhouse gas emissions resulting from carbon-based manufacturing processes as well as from energy-intensive extractive activities and agriculture production in the primary sector, all of which are part and parcel of export-oriented economic activities, largely — but not exclusively — produced for the articulated consumer markets in high income nations (e.g., McMichael 2008). Consistent with these arguments, recent longitudinal analyses indicate that the vertical flow of exports to high income nations contributes to growth in anthropogenic carbon dioxide emissions in developing nations, and like the above research on resource consumption, analyses suggest that these structural relationships have become increasingly ecologically unequal through time (e.g., Jorgenson n.d.; Stretesky and Lynch 2009).

A glaring limitation of the existing research in the ecologically unequal exchange tradition is the exclusion of Central and Eastern European (i.e., CEE) nations. In fact, and more broadly, very little comparative international research in the social sciences considers the social-structural causes of environmental degradation in CEE nations in the post Soviet era, meaning from the early 1990s to the present (for notable exceptions, see Andersen 2002; York 2008). Considering the underpinnings of the theory of ecologically unequal exchange as well as CEE nations being transition economies, this limitation is far beyond trivial. More specifically, these are nations that have recently transitioned, which is still an ongoing process, from socialist command economies to market demand economies (e.g., Bandelj and Mahutga 2010). With these significant changes, in the pursuit of economic development CEE nations to various degrees have all increased their focus on export-oriented production in the secondary and / or primary sectors, with much of the goods intended for export to wealthier nations in Western and Northern Europe as well as in North America and parts of Asia (World Bank 2010).

Increased income inequality and limited environmental regulation of private sector firms and their activities have accompanied the overall transition of CEE nations to market economies and their increasing focus on export-oriented production (e.g., Mahutga and Bandelj 2008). However, even with this focus on exports in particular and transition to market economies with minimal environmental regulations in general, growth in the volume of exports for many of the CEE nations has been modest at best (e.g., York 2008).[13] But while the volume of exports may not have grown substantially for all CEE nations in the past few decades, for most, especially from the mid-1990s on, the percentage of their exports being sent to high income nations has increased (see www.databank.worldbank.org). More specifically, for the thirteen CEE nations included in the panel analysis below, the mean percent of exports to high income nations increased from slightly above 42 percent in 1992 to approximately 60 percent in 2005. Such shifts are of particular relevance from an ecologically unequal exchange perspective, since the commonly tested propositions of the theory focus on the environmental impacts of the vertical flow of exports to high income, developed nations.

Turning to carbon dioxide emissions, for all of the CEE nations in the study, per capita carbon dioxide emissions (i.e., the dependent variable for this study) initially decreased in the early to mid-1990s, followed by periods of increases beginning at different time points and mostly continuing on through 2005. Such temporal dynamics for both the key predictor and the outcome suggest that their relationship — if one is actually observed — might have changed in magnitude through time. Indeed, prior research in the ecologically unequal exchange tradition has found relationships that are increasingly ecologically unequal, meaning that the magnitude of the effect of the vertical flow of exports on different environmental outcomes increased through time (e.g., Jorgenson and Clark 2009). Observed relationships that become increasingly ecologically unequal are consistent with the arguments of critical globalization scholars who posit that recent upsurges in the globalization of trade contribute to growing social and environmental inequalities between nations (e.g. Jorgenson and Kick 2006; Lofdahl 2002).

Overall, testing the proposition that the vertical flow of exports to high income nations contributes to anthropogenic carbon dioxide emissions in CEE nations is a unique opportunity to assess the validity and broader generalizeability of ecologically unequal exchange theory. As noted by Mahutga and Bandelj (2008), the CEE nations, with their transition economies, offer an important research site for assessing the environmental and social impacts of different forms of world economic integration, which certainly applies to ecologically unequal exchange theory since the perspective does indeed focus on the potential environmental and ecological consequences of the relational characteristics of international trade.

In the following analysis I attempt to address the above limitation by assessing the extent to which the vertical flow of exports to high income nations contributes to per capita carbon dioxide emissions in CEE nations. Consistent with past research in the ecologically unequal exchange tradition, I also employ appropriate measurement techniques to analyze if the effect of the vertical flow of exports on per capita emissions has increased, decreased, or remained the same in magnitude through time. I use a per capita measure of emissions as a dependent variable for theoretical and substantive reasons. Theoretically, per capita outcomes are quite appropriate from an international inequality perspective (e.g., Roberts

and Parks 2007), and ecologically unequal exchange is a structural inequality theory (e.g., Hornborg 1998; Jorgenson 2006; Rice 2007). Substantively, per capita measures are appropriate for this type of study since prior comparative-international research shows that the effect of total population size on total emissions is positive and close to proportional (e.g., Rosa et al. 2004) as well as statistically time-invariant in magnitude from 1960 to the present (Jorgenson and Clark 2010).

The analysis

The dataset

I analyze a perfectly balanced panel dataset with yearly observations from 1992 to 2005 for 13 Central and Eastern European (i.e., CEE) nations. These nations include Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Russian Federation, Tajikistan, Ukraine, and Uzbekistan. Other CEE nations are excluded from the analysis since yearly observations for the dependent variable and independent variables are unavailable for each year between 1992 and 2005. Considering that a key focus of the current study is if the magnitude of the effect of the vertical flow of exports on emissions changed through time, a perfectly balanced panel dataset is preferred.[4] The dataset, which consists of 182 total observations, is available from the author upon request.

Model estimation technique

I use a time-series cross-sectional Prais-Winsten (PW) regression model with panel-corrected standard errors (PCSE), allowing for disturbances that are heteroskedastic and contemporaneously correlated across panels.[5] I correct for AR(1) disturbances (i.e., first-order autocorrelation) within panels, and since there is no theoretical basis for assuming the process is panel specific, I treat the AR(1) process as common to all panels (Beck and Katz 1995:638). I calculate and employ dummy variables to control for panel-specific disturbances (i.e., unit-specific intercepts), which serves as fixed effects by controlling for potential unobserved heterogeneity that is temporally invariant within countries (Allison 2009). I also include a linear time control for the yearly observations (i.e., 1992=1, 2005=14), which lessens the likelihood of biased model estimates resulting from outcomes and predictors with relatively similar time trends (Wooldridge 2005).[6] The general model is as follows:

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

Subscript i represents each unit of analysis (i.e., country), subscript t represents the time period, and y_{it} is the dependent variable for each country at each time period. $\beta\chi_{it}$ represents the vector of coefficients for predictor variables that vary over time, u_i is the country-specific disturbance term, w_t is the time control that is constant across all countries, and e_{it} is the disturbance term unique to each country at each point in time. The dummy variables for each country are employed to control for u_i.[7]

To normalize the positively skewed distributions, prior to the panel analyses I log (ln) the dependent variable and all independent variables except the linear time control.[8] Such an approach is commonplace for methodological reasons (e.g., Dietz and Kalof 2009), but it is also foundational for the structural human ecology orientation, particularly comparative-international research in the orientation that examines the human drivers of global environmental change (see http://stirpat.org/ for a thorough overview). This modeling technique, where all predictors and the outcome are converted into logarithmic form, is also known as a type of elasticity model. The coefficients of an elasticity model are easy to interpret for continuous variables, which applies here since all variables in the current study are continuous. The coefficient for each continuous independent variable is the estimated percentage change in the dependent variable associated with a 1 percent increase in the independent variable, controlling for other factors in the model (see also Dietz et al. 2009; Rosa, York, and Dietz 2004; York 2008).

Dependent variable

The dependent variable, obtained from the World Resources Institute online Earthtrends database (www.earthtrends.wri.org/, accessed November 11, 2010), is carbon dioxide emissions per capita in metric tons. These data represent the mass of carbon dioxide per person produced during the combustion of solid, liquid, and gaseous fuels, as well as from gas flaring and the manufacture of cement. They do not include emissions from land use change or emissions from bunker fuels used in international transportation. More specifically, the emissions data come from the World Resources Institute's Climate Analysis Indicators Tool (CAIT), which is an information and analysis tool on global climate change. CAIT provides a comprehensive and comparable database of greenhouse gas emissions data (including all major sources and sinks) and other climate-relevant indicators. In order to provide the most complete and accurate dataset, CAIT compiles data from three sources — the Carbon Dioxide Information Analysis Center, the International Energy Agency, and the Energy Information Administration.

Independent variables

The independent variable of interest in this study is percent of exports to high income nations (HINs), which I gather from the online version of the World Bank's World Devel-

opment Indicators (www.databank.worldbank.org, accessed January 24, 2011). These data refer to the sum of merchandise exports from the reporting economy to high income economies according to the World Bank classification of economies as of July 1, 2009.[9] The measure is expressed as a percentage of total merchandise exports by the economy, and are computed only if at least half of the economies in the partner country group had non-missing data. Prior cross-national tests of ecologically unequal exchange theory use this as a measure of the vertical flow of exports for testing hypothesis derived from ecologically unequal exchange theory (e.g., Rice 2007; Shandra et al. 2009). Other studies use a different measure that was initially developed by Jorgenson (2006) for testing the arguments of the theory (e.g., Jorgenson and Clark 2009). This other measure, usually referred to as "weighted export flows", quantifies the relative extent to which the exports of a nation are sent to more-developed nations. While either variable is suitable for the current analysis, I employ the percent of exports to HICs as the key predictor since the interpretation of this variable and its estimated effect is much more straightforward, and data are more readily available for this variable for the CEE nations in the study than for Jorgenson's weighted export flows measure. Further, for samples of other nations these two measures tend to be correlated at or above .90 (see Jorgenson n.d.).

To examine if the magnitude of the effect of percent of exports to HINs on per capita emissions has increased or decreased through time, I calculate and include an interaction between this variable and the linear year variable where 1992=1 and 2005=14. Such an interaction between an independent variable and time is common in past comparative international research on various environmental and public health outcomes (e.g., Brady, Kaya, and Beckfield 2007; Jorgenson and Burkholz 2010), including past research in the ecologically unequal exchange tradition (e.g., Jorgenson and Clark 2010).

Consistent with the majority of prior cross-national research, I include gross domestic product per capita (GDP per capita) as a measure of a nation's level of economic development. These data are measured in 2000 constant U.S. dollars and obtained from the World Bank (2010). For theoretical reasons one should expect to observe positive associations between per capita greenhouse gas emissions and GDP per capita (e.g., Gould, Pellow, and Schnaiberg 2008), and prior research consistently reveals their positive relationship (e.g., Jorgenson 2009; Rosa et al. 2004; York 2007).

I also include exports as percent GDP, which controls for the extent to which a country is integrated in the world economy. These data are also obtained from the World Bank (2010). Prior research shows a positive association between international trade and carbon dioxide emissions (e.g., Roberts and Parks 2007; Schofer and Hironaka 2005). Of particular importance for the current analyses, including this measure allows for assessing the extent to which the vertical flow of exports to high-income nations affects per capita emissions in CEE nations, net of relative levels of trade.

I include measures of urban population, which quantifies the percent of a country's population residing in urban areas. These data are gathered from the World Bank (2010). Generally speaking, urban political-economy approaches posit positive associations between per capita emissions and levels of urbanization (e.g. Clark and York 2005; Dickens 2004), and prior research yields such results (e.g., Lankao, Nychka, and Tribbia 2008; Roberts and Parks 2007).

I control for the relative size on non-dependent populations, which specifically refers to the percentage of the total population of a given nation that is in the age group 15 to 64. Population is based on the de facto definition of population as described below for the measure of total population. I obtain the measures of non-dependent population from the World Bank (2010). Prior research shows that the relative size of non-dependent populations is a primary contributor to growth in emissions and energy consumption (e.g., York 2007), and of particular relevance for this study, the relative size of non-dependent populations grew for all of the CEE nations in the dataset during the 1992 to 2005 period (World Bank 2010; see also York 2008).

Table 1 provides the descriptive statistics for all variables included in the reported panel model estimates.[10]

Table 1. Descriptive Statistics

	Mean	S.D.	Minimum	Maximum
Carbon Dioxide Emissions per capita	1.619	.665	.482	2.802
Percent of Exports to HINs	3.755	.561	1.742	4.510
Percent of Exports to HINs X Year	28.999	17.042	2.258	61.948
GDP per capita (ln)	6.871	.943	4.805	8.744
Exports as Percent of GDP	3.722	.415	2.270	4.593
Urban Population as Percent of Total Population	4.007	.298	3.273	4.296
Non-Dependent Population	4.156	.073	3.960	4.264
Year	7.500	4.042	1.000	14.000

Notes:
n = 182; 14 yearly observations for 13 CEE nations, 1992-2005;
all variables except "year" are logged (ln);
S.D. refers to standard deviation

Results

Table 2 presents the findings for the panel analysis. Three models are reported. Model 1 consists of percent of exports to HINs, GDP per capita, exports as percent of GDP, urban population, non-dependent population, and the linear time control, labeled as "year". Model 2 includes all predictors in the first model as well as the interaction between percent of exports to HINs and year. Model 3, which is described in greater detail below, is a type of sensitivity analysis to assess if the observed effect in Model 2 of the interaction between percent of exports to HINs and year is spurious due to high collinearity. Unstandardized coefficients and corresponding standard errors are reported for each predictor as well as the r-square, rho (autocorrelation parameter), sample size (n), number of countries, and number of observations per country for each model. The very high r-square value for both models should be expected since they include unreported unit-specific intercepts as well as the reported time control. In fact, a model that includes only the time control and unit-specific intercepts results in an r-square of .936. Prior to discussing the estimated effects of percent of exports to HINs and its interaction with time, I briefly summarize the results concerning the additional independent variables.

Table 2. Unstandardized Coefficients for the Regression of Per Capita Carbon Dioxide Emissions, 1992-2005 on Percent of Exports to High Income Nations and other Selected Independent Variables: Fixed Effects PW Regression Model Estimates with PCSE and an AR(1) Correction for 13 Central and Eastern European Countries

	Model 1	Model 2	Model 3
Percent of Exports to HINs	-.073**	-.186***	-.186***
	(.026)	(.031)	(.031)
Percent of Exports to HINs X Year		.026***	.026***
		(.004)	(.004)
GDP per capita	.420***	.326***	.326***
	(.056)	(.052)	(.052)
Exports as Percent of GDP	-.003	-.017	-.017
	(.024)	(.023)	(.023)
Urban Population as Percent of Total population	-.132	.115	.115
	(.640)	(.547)	(.547)
Non-Dependent Population	5.175***	5.554***	5.554***
	(.869)	(.759)	(.759)
Year	-.062***	-.163***	-.054***
	(.005)	(.020)	(.005)
Constant	-22.050***	-24.440***	-24.491***
	(4.502)	(3.686)	(3.688)
R-squared	.969	.976	.976
n	182	182	182
Number of Countries	13	13	13
Number of Observations Per Country	14	14	14
rho	.587	.499	.499

Notes:
all models include unreported unit-specific intercepts;
unstandardized coefficients flagged for statistical significance;
standard errors in parentheses; ***p<.001 **p<.01 *p<.05 #p<.10 (two-tailed tests);
HINs refers to high income nations; all variables except "year" are logged (ln)

The effects of GDP per capita and non-dependent population are positive and statistically significant in both models. These findings are quite consistent with past comparative international research on CEE nations and on larger and broader samples of countries as well as established political-economic and human-ecological theorizations concerning the environmental impacts of economic development and demographic characteristics. However, the effects of urban population and exports as percent of GDP are nonsignificant, which contrast with common results in prior cross-national investigations of anthropogenic greenhouse gas emissions and other related outcomes. While not the focus of the current study, the null finding for urban population could be suggestive of the potential problems in over-generalizing urban / environment relationships, or possibly be a function of limitations in measurement. Urban areas are far from monolithic in structure and social organization (Kleniewski 2002; Smith 1996), and prior longitudinal research on less-developed countries shows that different urban characteristics, particularly urban slum prevalence and the percent of populations living in urban areas, have opposite effects on fossil fuel consumption and thus carbon dioxide emissions (Jorgenson, Rice, and Clark 2010).

Turning to the nonsignificant effect of exports as percent GDP, it appears that the relative level of exports for CEE nations does not directly influence their levels of per capita emissions, at least during the 1992 to 2005 period, which contrasts the results of York's (2008) study of development and emissions in CEE nations for a shorter 1992 to 2000 time frame. However, the focus of this study is on the environmental impacts of the structure of international trade in the context of the vertical flow of exports to high income nations (HINs) as a mechanism of ecologically unequal exchange relationships, and the extent to which such effects might change in magnitude through time. We now turn to a discussion of those estimated effects.

The findings for Model 1 indicate that the effect of percent of exports to HINs is negative and statistically significant. By itself, this would suggest that structural relationships between CEE nations and high income nations were ecologically *beneficial* (emissions-wise) for the former from 1992 to 2005, at least in the form of trade flows to the latter.

However, such a conclusion assumes that the effect of the vertical flow of exports to HINs was time-invariant, meaning the same in magnitude and direction for the entire period of study. The results of Model 2 paint a more complex and dynamic picture. More specifically, the effect of the interaction between percent of exports to HINs and year is positive and statistically significant, which suggests that the effect of the vertical flow of exports on emissions in CEE nations is not time-invariant. The positive effect suggests that through time this particular type of structural relationship became *progressively less environmentally beneficial* for CEE nations, and in fact became *environmentally harmful, ecologically unequal, and increasingly so* from 2000 on, at least through 2005.

To assess if the results concerning the interaction between percent exports to HINs and time are spurious due to the high collinearity between the interaction and time itself, in a sensitivity analysis, reported as Model 3, I first regress the interaction on the linear time control and then I employ the residuals, which are perfectly uncorrelated with time, in panel a model of per capita carbon dioxide emissions that includes the same predictors as in Model 2. The results of the sensitivity analysis with the residuals are close to identical with the reported findings, suggesting that the estimated coefficient for the interaction is not spurious for such reasons. More specifically, the only differences are the estimated coefficient for the linear time control, which changes from -.163 to -.054, and the estimated constant, which changes from -24.440 to -24.491. The estimated coefficient for the "residualized" form of the interaction between percent exports to HINs and time is identical to the reported coefficient for the interaction in its regular form in Model 2 (i.e., a value of .026).

Figure 1 shows the estimated effect of the percent of exports to HINs on per capita emissions in 1992, 1999, 2000, and 2005. I choose to focus on these four particular years because they represent the first year and last year represented in the panel study as well as the two years where the effect of the vertical flow of exports on per capita emissions went from being negative to positive. These coefficients are calculated by (1) multiplying the estimated value of the coefficient for the interaction (i.e., .026) by the number of years past the reference year, and then (2) adding that multiplied value to the reference year coefficient, which is for the year 1992 and has a value of -.186, since in the estimated model that includes the interaction the coefficient for percent of exports to HINs is for the reference year. For example, to calculate the value for the effect in 1999, I first multiply the value of the interaction by 7 (i.e., 1999-1992=7), which results in a value of .182. Second, .182 is added to -.186, and results in a value of -.004, which represents the effect of percent of exports to HINs on per capita emissions in the year 1999.

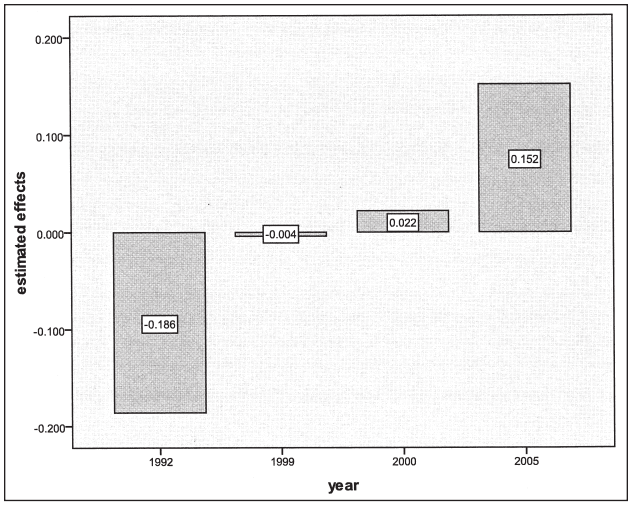

Figure 1. Estimated Effects of Percent of Exports to High Income Nations

The differences in the estimated effects of the percent of exports to HINs for the beginning point (1992) and end point (2005) highlight quite clearly how in a relatively short period of time, CEE nations, which are transition economies that experienced increased world economic integration during this time period, went from experiencing apparent environmentally friendly benefits to ecologically unequal consequences of focusing on exports to HINs. Further, coupled with the non-significant effects of exports as percent of GDP, these results highlight the potential differences in the environmental impacts of the structure of international trade and the relative levels of trade, and especially the extent to which they can differ for nations experiencing rapid integration into the world economy.

Conclusion

The purpose of this study was to evaluate the proposition derived from ecologically unequal exchange theory that the vertical flow of exports to high income nations contributes to growth in anthropogenic carbon dioxide emissions in Central and Eastern European (CEE) nations from 1992 to 2005. Initial findings suggest the opposite: the effect of the percent of exports to high income nations on emissions is negative, meaning that such structural relationships are environmentally beneficial and not ecologically unequal for CEE nations, particularly as they transitioned to market based economies in the post-Soviet era. However, additional results suggest that the observed negative effect, which is modeled as and thus assumed to be time-invariant, hides the actual temporal dynamics and shifts in the relationship. As illustrated by the second and third models in the panel analysis, the estimated

coefficient for the interaction between the percent of exports to high income nations and time is positive and statistically significant. In other words, this particular structural relationship between CEE nations and high income nations might have started off as environmentally beneficial for the former at the beginning of the post-Soviet era. However, it quickly became less beneficial and turned into an environmentally harmful relationship for CEE nations, and began contributing to growth in their per capita carbon dioxide emissions in 2000 and increasingly so through 2005, the latter of which serves as the endpoint for the study. Thus, in the context of carbon dioxide emissions, it appears that structural relationships — at least in the form of the vertical flow of exports — between CEE nations and high income nations became increasingly ecologically unequal for the former, and in a relatively short period of time.

Due to increases in (1) the availability of adequate panel data and (2) the accessibility of employing sophisticated model estimation techniques, cross-national longitudinal analyses are becoming commonplace in the environmental social sciences as well as other multidisciplinary areas of research. This broader trend is beneficial and will lead to better scientific inquiry, since such forms of comparative research are relatively more rigorous and effective for hypothesis testing. As this particular research illustrates, an added advantage of longitudinal analysis is the clear ability to assess if the magnitude of relationships between outcomes and predictors increase or decrease through time, or remain statistically time-invariant. Many foundational theories of society / nature relationships, including ecologically unequal exchange theory, suggest potential magnitude shifts. Not considering such temporal dynamics in this study would have resulted in substantive conclusions that are greatly inaccurate and potentially harmful from a policy perspective, not to mention an invalid assessment of the tested theory. Other scholars should be more mindful of these important advantages of longitudinal modeling techniques and exploit them in future research when appropriate.

Overall, the results of this study, particularly the second portion of the analysis, provide additional and unique support for the theory of ecologically unequal exchange. The support is unique since all prior comparative international research in this tradition failed to consider its applicability and validity for the transition economies of the CEE nations. More broadly, very little quantitative comparative-international research in the social sciences exists concerning the political-economic and demographic causes of environmental harms in this region of the world. Besides its specific contribution to scholarship in the ecologically unequal exchange tradition, the key findings for this study along with the additional results concerning the impacts of development and the relative size of non-dependent populations enhance our collective understanding of society / nature relationships in CEE nations as they experience noteworthy domestic changes as well as increasing integration into the world economy. Indeed, as suggested by Mahutga and Bandelj (2008), the CEE nations offer an important research site for assessing the environmental and social impacts of different forms of world economic integration and changing domestic conditions. It is my hope that this brief study will encourage other environmental social scientists to pursue future empirical investigations of the human dimensions of environmental change in this important and greatly overlooked region as well as other overlooked macro-regions in the world.

Endnotes

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2 For an expanded discussion of these challenges, see Jorgenson, Austin, and Dick (2009).

3 Even though the volume of exports didn't increase substantially for all CEE nations during the early stages of transitioning to market economies, York (2008) finds some evidence that the level of exports as percent GDP positively affected carbon dioxide emissions in CEE nations during the 1992 to 2000 period.

4 See Jorgenson and Clark (2010) for an extended discussion about why a perfectly balanced panel dataset is preferred for this type of inquiry.

5 I employ PCSE because the feasible generalized least-squares estimator that is often used to analyze panel data produces standard errors that can lead to extreme overconfidence with panel datasets that do not have many more time periods than panels (Beck and Katz 1995).

6 The analyses are conducted with the "xtpcse" suite of commands in Stata (version 9) software.

7 Overall, this modeling approach is robust against potentially omitted control variables and more closely approximates experimental conditions than other panel model approaches (Hsiao 2003).

8 However, the model estimates are substantively consistent with the reported findings when the dependent variable and the independent variables are not log transformed.

9 Nations are considered high income if they fall into the upper quartile of the World Bank's income classification of countries.

10 As noted by an anonymous reviewer, recent comparative-international research also links growth in carbon dioxide emissions to militarization in the forms of military expenditures per soldier and military personnel as percent of total labor force (e.g., Clark, Jorgenson, and Kentor 2010; Jorgenson, Clark, and Kentor 2010). While I would prefer to control for such measures in the current study, they are unavailable for enough years for the CEE nations to allow for their inclusion.

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