The Transnational Organization of Production, the Scale of Degradation, and Ecoefficiency: A Study of Carbon Dioxide Emissions in Less-Developed Countries

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Abstract

Drawing from prior research and sociological theorization, this study investigates (1) if the transnational organization of production in the context of foreign investment dependence contributes to overall levels of environmental degradation, and (2) if transnationally controlled manufacturing is relatively more or less ecoefficient. To do so, fixed effects panel regression analyses of 37 less-developed countries from 1975-2000 are conducted to assess the effects of secondary sector foreign investment on total carbon dioxide emissions and emissions per unit of production. Findings indicate that foreign investment in manufacturing is positively associated with both outcomes. Additional results suggest that total population, level of development, and export intensity are all positively associated with total emissions and emissions per unit of production. While supporting theorization about the environmental impacts of foreign investment, this study also underscores the importance of considering both human-ecological and political-economic factors when investigating human-caused environmental degradation.

Keywords: *global warming and climate change, globalization, political-economy, environmental sociology, greenhouse gas emissions*

Introduction

A growing number of sociologists and other social scientists utilize their theoretical and methodological tools to investigate how the structure of the world-economy impacts the environment. In this body of research, increasing attention is paid to how the transnational organization of production in the context of inward foreign investment contributes to the emission of greenhouse gases and other forms of environmental degradation, particularly in less-developed countries. The current study contributes to the burgeoning literature on foreign investment and the environment by investigating (1) the extent to which foreign investment in manufacturing contributes to overall levels of environmental degradation and (2) if transnationally controlled manufacturing is relatively more or less ecoefficient. To do so, ordinary least squares fixed effects panel regression analyses of 37 less-developed countries from 1975-2000 are conducted to assess the effects of secondary sector foreign direct investment on both total carbon dioxide emissions and emissions per unit of production. The tested models include a variety of additional predictors derived from the structural human ecology tradition as well as different political-economic perspectives. Results indicate that foreign investment in manufacturing is positively associated with both total emissions and emissions per unit of production, net of the effects of population, development, export intensity, democratization, and other factors.

The importance of this research can not be overstated. It is widely known that carbon dioxide emissions are the largest anthropogenic contributor to global warming and climate change (e.g. Houghton et al. 2001; Intergovernmental Panel on Climate Change 2007; National Research Council 1999). Total carbon dioxide emissions and emissions per unit of production both increased during the past few decades in less-developed countries (World Resources Institute 2005). In fact, within less-developed countries, total emissions more than doubled, while emissions per unit of production increased from 1980 to 1996 and then "plateaued" from 1997 to 2000. The relative presence of foreign investment stocks within less-developed countries also increased dramatically during recent decades from 4% of overall GDP in 1980 to almost 28% overall GDP in 2000 (OECD 2001; United Nations 1992, 1994, 1996, 2000, 2003). Most importantly, the upward trajectories of total carbon dioxide emissions and the accumulated stocks of foreign investment as % overall GDP in less-developed countries for those two decades are highly correlated (Pearson's correlation coefficient of approximately .800), and the temporal trajectories of foreign investment presence (% overall GDP) and emissions per unit of production from 1980 to 2000 in less-developed countries are moderately correlated as well (Pearson's correlation coefficient of approximately .450)[2].

In the next section I summarize prior research and theorization concerning the potential effects of foreign direct investment, with a particular focus on the ecostructural approach to investigating the environmental impacts of the transnational organization of production in the context of foreign investment dependence. Next, I describe the panel regression method used to analyze the effects of secondary sector foreign investment on both of the current study's outcomes, I discuss the countries included in the unbalanced panel dataset, and I describe all dependent and independent variables included in the analyses. During the latter, I provide brief theoretical explanations for the inclusion of each additional predictor. After the variable descriptions, I present and discuss the findings for the analyses, which are followed by a brief conclusion that summarizes the key results of the study as well as some of the next steps in this research agenda.

Prior Research and Theorization

In macrosociology, a great deal of theoretical and empirical attention is paid to the potential impacts of foreign investment. The most broadly known and debated sociological orientation in this area of scholarship is the theory of foreign investment dependence (e.g. Bornschier and Chase-Dunn 1985; Bornschier et al. 1978; Chase-Dunn 1975). This longstanding theory generally asserts that the accumulated stocks of foreign investment make a less-developed country more vulnerable to different transnational and global political-economic conditions, which often leads to a variety of negative consequences for domestic populations within investment dependent nations. The vast majority of prior research that tests hypotheses derived from the theory of foreign investment dependence investigates the effects of foreign investment on economic development, domestic income inequality, food security, urban primacy, overurbanization, and other social outcomes (e.g. Alderson and Nielson 1999; Bradshaw 1987; Dixon and Boswell 1996; Firebaugh 1996; Jenkins and Scanlan 2001; Kentor 2001; Kentor and Boswell 2003; London and Smith 1988; Wimberly and Bello 1992). Building on this area of prior research and theorization, a growing number of social scientists have begun to theorize about and investigate the extent to which the transnational organization of production in the context of foreign investment dependence impacts the environment in less-developed countries (e.g. Grimes and Kentor 2003; Jorgenson 2006a, 2006b, 2007a, 2007b; Kentor and Grimes 2006). Similar to Grant et al. (2002), to highlight its overall structural political-economic orientation and relevance for environmental sociology, Jorgenson (2003) and Jorgenson et al. (2007) characterize the burgeoning area of sociological research on foreign investment and the environment as a form of ecostructuralism.

Partly through the influence of global neoliberal institutions, less-developed countries often focus on creating attractive business conditions for foreign investors and transnational corporations. These attractive business conditions include relatively lower and less domestic environmental regulations for productive activities in different sectors of the economy (e.g. Clapp 1998; Frey 2003). In a related vein, due to the perceived or real threat of capital flight, many less-developed countries are reluctant to enforce existing environmental and labor regulations (e.g. Wallerstein 2005), and recent research shows that less-developed countries are often less likely than more-developed countries to ratify different international environmental treaties (e.g. Roberts 1996; Roberts et al. 2004; Roberts and Parks 2007). Globalization scholars characterize these political-institutional dynamics as a type of deregulation (e.g. Robinson 2004), which is part of an overall form of political globalization (Chase-Dunn et al. 2000; Chase-Dunn and Jorgenson 2007), or what Phil McMichael (2004) aptly refers to as the "globalization project."

With these emergent political-institutional dynamics, many social scientists argue that a large proportion of foreign investment in less-developed countries finances highly polluting and ecologically inefficient manufacturing processes and facilities, much of which are outsourced from developed countries (e.g. Grimes and Kentor 2003; Jorgenson 2006b; Jorgenson et al. 2007). In general, transnational firms benefit economically from this form of environmental cost shifting, since different ecologically inefficient and highly polluting manufacturing processes often include more outdated and inexpensive machinery and materials. This also allows transnational firms to distance themselves in the public eye from the environmental and related human well being costs of their productive activities (Princen 2002). Besides lessening the likelihood of transnational firms being subject to increased regulations, restrictions, and fines by domestic political institutions in the countries of their headquarters, the buying habits of consumers within more-developed countries are less likely to be influenced since they are often less aware of the environmental impacts associated with the production of the commodities they consume.

Moreover, partly resulting from a lack of tax revenues and cuts in public spending, the power generation techniques within many less-developed countries tend to be fossil fuel dependent and considerably less eco-efficient, and many of these types of facilities generate at least some of the electricity used by transnationally-owned manufacturing centers (Kentor and Grimes 2006). In addition to production equipment and power generation techniques, the transportation vehicles owned and used by foreign-owned manufacturing enterprises in less-developed countries for the movement of inputs, outputs, and labor are more likely to be outdated and

energy-inefficient (Jorgenson 2007b). Also, the "on-the-ground" transportation infrastructure of many less-developed countries tends to be more poorly maintained than in more-developed countries. For example, roadways are less likely to be paved on a regular basis, and rail systems are more likely to be spotty in different areas, and these problematic conditions can lead to the increased use of fossil fuels for the transportation of raw materials, manufactured goods, and labor (Grimes and Kentor 2003).

Prior cross-national research supports the above assertions. For example, Grimes and Kentor (2003) and Kentor and Grimes (2006) link foreign investment to growth in total carbon dioxide emissions in less-developed countries. Shandra et al. (2004) identify a positive association between foreign investment and per capita carbon dioxide emissions, and Roberts et al. (2003, 2006) find some evidence of an association between foreign investment and carbon dioxide emissions per unit of production. However, due to prior data limitations, these studies focus on the effect of foreign investment in all sectors combined, which could be somewhat problematic since recently available data indicate that foreign investment in the primary and secondary sectors are moderately correlated at best[3] (e.g. OECD 2001; United Nations 2003). More importantly, theorization in this particular body of literature tends to focus on manufacturing-related structural conditions, activities, and their environmental impacts. Using the recently available sector-level measures, Jorgenson et al. (2007) link secondary sector foreign investment to per capita carbon dioxide emissions, per capita carbon monoxide emissions, per capita volatile organic compounds emissions, and per capita nitrogen oxides emissions. Jorgenson (2006b; 2007b) also finds a positive association between secondary sector foreign investment and growth in industrial organic water pollution intensity (emissions per day per worker), and a positive effect of foreign investment in manufacturing on total carbon dioxide emissions and total organic water pollution emissions.

With few exceptions (Jorgenson 2007b; Jorgenson et al. 2007), because of data availability issues for both predictor and outcome variables, the regression methods used in prior studies on the environmental impacts of foreign investment are cross-sectional by design (e.g. Jorgenson 2006a; Roberts et al. 2003, 2006) or involve "static score panel models" (e.g. Finkel 1995) that regress the outcome at "time 2" on the outcome at "time 1" as well as other statistical controls at "time 1" (e.g. Grimes and Kentor 2003; Jorgenson 2006b; Shandra et al. 2004). Cross-sectional models are stationary in character, which limits causal inferences (Twisk 2003), and static score panel models are relatively limited in dealing with unmeasured time-invariant variables (Wooldridge 2002). Panel regression methods do indeed exist (e.g. GLS random effects and OLS fixed effects) that can more effectively handle these and many other important issues, such as autocorrelation. Fortunately, adequate panel data for independent and dependent variables in this area of research are now available, which allows for the use of more rigorous panel regression techniques, and also enables researchers to broaden the temporal scope of their investigations. Drawing from ecostructural theorization and prior empirical work, in the analyses that follow I employ more rigorous panel regression methods to investigate if foreign direct investment in manufacturing contributes to both total carbon dioxide emissions and carbon dioxide emissions per unit of production in less-developed countries from 1975 to 2000. I also include a variety of additional theoretically relevant predictors, which I discuss below.

Methods

To investigate the extent to which secondary sector foreign direct investment contributes to (1) total carbon dioxide emissions and (2) carbon dioxide emissions per unit of production, I use STATA version 9 software to estimate ordinary least squares (OLS) fixed effects (FE) models[4] (Frees 2004; Hamilton 2006). In all OLS FE models I include a correction for first-order autocorrelation (i.e. AR[1] correction). Not correcting for autocorrelation can often lead to biased standard error estimates (Greene 2000; Wooldridge 2002).

In the comparative social sciences, OLS FE panel regression is one of the most commonly used methods designed to correct for the problem of heterogeneity bias (Halaby 2004). Heterogeneity bias in this context refers to the confounding effect of unmeasured time-invariant variables that are omitted from the regression models. To correct for heterogeneity bias, FE models control for omitted variables that are time invariant but that do vary across cases. This is done by estimating unit-specific intercepts, which are the fixed-effects for each case. FE models are quite appropriate for this type of cross-national panel research because time invariant unmeasured factors such as natural resource endowments and geographic region could affect environmental outcomes (e.g. Jorgenson 2007b). The FE approach also provides a stringent assessment of the relationship between foreign investment and carbon dioxide emissions, given that the associations between secondary sector foreign investment and both outcomes are estimated net of unmeasured between-country effects (Beckfield 2007). Overall, this modeling approach is quite robust against missing control variables and closely approximates experimental conditions (Hsiao 2003). Results of Hausman tests also indicate that FE models are more appropriate than random effects [RE] models for the current analyses.

The notation for the estimated FE models is as follows:

$$y_{it} = a + B_1x_{it1} + B_2x_{it2} + ... + B_kx_{itk} + u_i + w_t + e_{it}$$

The subscript i represents each unit of analyses (country) and the subscript t represents the time period, y_{it} is the dependent variable for each country at each time period, a is the constant, x_{itk} represents the independent variables for each country at each point in time, B_k represents the coefficient for each independent variable, u_i is the country-specific disturbance term that is constant over time, w_t is the period specific disturbance term that is constant across all countries in the analysis, and e_{it} is the disturbance term specific to each country at each point in time.

The Dataset

The analyzed sample includes all less-developed countries in which data are available for both of the dependent variables and all independent variables for a minimum of 3 years,[5] ranging from 1975 to 2000. Less-developed countries are identified as those not falling in the top quartile of the World Bank's income quartile classification (based on level of economic development) for countries (World Bank 2005). Using these criteria, the sample for the current study is an unbalanced panel dataset consisting of 3 to 26 yearly observations for 37 less-developed countries. This results in an overall sample of 530, which is substantially larger than most prior research in this tradition. Table 1 lists the 37 countries included in the analyses as well as the number of observations and years included per country.[6]

Table 1. Countries Included in the Analyses (N=530)

	Number of Observations	Number of Years
Argentina	17	1981, 1983-91, 1994-2000
Bangladesh	19	1982-2000
Benin	3	1990, 1995, 2000
Brazil	25	1976-2000
Cameroon	3	1990, 1995, 2000
China	8	1988-1993, 1995, 2000
Colombia	26	1975-2000
Costa Rica	26	1975-2000
Dominican Rep.	26	1975-2000
Ecuador	26	1975-2000
El Salvador	4	1985, 1990, 1995, 2000
Ghana	3	1990, 1995, 2000
Haiti	3	1990, 1995, 2000
Honduras	6	1989-1990, 1995, 1998-2000
India	26	1975-2000
Indonesia	26	1975-2000
Kenya	3	1990, 1995, 2000
Malaysia	26	1975-2000
Mexico	26	1995-2000
Morocco	3	1990, 1995, 2000
Nepal	10	1990, 1992-2000
Nicaragua	3	1990, 1995, 2000
Nigeria	24	1975-1997, 2000
Pakistan	24	1977-2000
Panama	22	1975-1995, 2000
Paraguay	4	1990, 1993, 1995, 2000
Peru	25	1976-2000
Philippines	21	1980-2000
Rwanda	3	1990, 1995, 2000
Senegal	3	1990, 1995, 2000
Sri Lanka	16	1985-2000
Thailand	21	1980-2000
Turkey	14	1978-1984, 1990-1995, 2000
Uganda	3	1990, 1995, 2000
Venezuela	21	1980-2000
Vietnam	8	1990, 1994-2000
Zimbabwe	3	1990, 1995, 2000

Variables Included in the Analyses

Dependent Variables

1. Total carbon dioxide emissions represent the mass of carbon dioxide produced during the combustion of solid, liquid, and gaseous fuels, as well as from gas flaring and the manufacture of cement. These data, which are measured in thousand metric tons and logged (ln) to correct for excessive skewness, are gathered from the World Resources Institute (2005). The values were converted to the actual mass of carbon dioxide from original values showing the mass of elemental carbon; the World Resources Institute multiplied the carbon mass by 3.664, which is the ratio of the molecular mass of carbon dioxide to that of carbon. This also applies to the second dependent variable.

2. Carbon dioxide emissions per unit of GDP measures the quantity of carbon dioxide released into the atmosphere for each million dollars of Gross Domestic Product (GDP) in a country or region. These data, which I use as measures of relative ecoefficiency (Roberts and Grimes 1997; Roberts et al. 2003, 2006; see also York et al. 2004), are obtained from the World Resources Institute (2005) and measured as metric tons of emissions per million constant 1995 United States dollars. Consistent with the first dependent variable, these estimates refer to carbon dioxide emissions produced during the combustion of liquid, solid, and gaseous fuels, as well as from the manufacture of cement and gas flaring. To obtain comparable series of constant price data, the World Bank rescales GDP and value added by industrial origin to a common reference year, currently 1995. Like the total emissions estimates, measures of emissions per unit GDP are logged (ln) to correct for excessive skewness.

Independent Variables

1. Accumulated stocks of secondary sector foreign direct investment as percentage of total gross domestic product is

used to investigate the relationship between foreign investment in manufacturing and both outcomes. These data are logged (ln) to correct for excessive skewness. Stocks as percentage of total GDP is the most commonly used measure of foreign investment dependence in the comparative social sciences (e.g. Alderson and Nielson 1999; Dixon and Boswell 1996; Kentor 2001) as well as a measure of the relative control of the transnational organization of production (e.g. Jorgenson 2006b, 2007b). The foreign direct investment stocks data are obtained from the Organization for Economic Co-Operation and Development's *International Direct Investment Statistics Yearbook* (2001) and the United Nations' *World Investment Directories* (1992, 1994, 1996, 2000, 2003). These data consist of investment in food and beverages, tobacco, textiles and clothing, leather, wood and wood products, publishing and printing, coke, petroleum products, nuclear fuel, chemicals and chemical products, rubber and plastic products, non-metallic mineral products, metal and metal products, machinery and equipment, electrical and electronic equipment, precision instruments, motor vehicles and other transport equipment, other manufacturing, and recycling (United Nations 1992, 1994, 1996, 2000, 2003; OECD 2001). Total GDP data are measured in 1995 US dollars, and gathered from the World Bank (2005).

2. Total population is measured in thousands and logged (ln) to correct for excessive skewness. These data are obtained from the World Bank (2005). The measures of total population are based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. Refugees not permanently settled in the country of asylum are generally considered to be part of the population of their country of origin. Sociologists working in the structural human ecology tradition argue that population is a key driver of scale-level environmental outcomes, such as total carbon dioxide emissions (e.g. Dietz and Rosa 1997; Rosa et al. 2004). Larger populations tend to have greater cumulative impacts on the environment. While there is no clear theoretical reason for doing so, I also include total population as a statistical control in the analyses of emissions per unit of production (see also Roberts and Parks 2007). Arguably, controlling for total population while estimating OLS FE models will allow for an even more rigorous statistical investigation of the relationship between secondary sector foreign investment and relative ecoefficiency (i.e. emissions per unit of GDP).

3. Gross domestic product (GDP) per capita is included as a control for level of economic development. These data, which I gathered from the World Bank (2005), are measured in 1995 US dollars and logged (ln) to correct for excessive skewness. Political-economic approaches, including treadmill of production theory (Schnaiberg and Gould 1994) and world-systems theory (Jorgenson and Kick 2006; Roberts and Grimes 2002) as well as structural human ecology perspectives (e.g. York et al. 2003) all argue that development or affluence is a key macro-level driver of environmental degradation measured by scale. Indeed, prior research on total carbon dioxide emissions consistently shows a positive association between this outcome and level of development (e.g. Jorgenson 2007b; Rosa et al. 2004). Turning to emissions per unit of production, world-systems scholars, such as Roberts et al. (2003, 2006), assert that middle-developed or semiperipheral countries tend to have enough fossil fuel dependent technologies to compete on the world market but not enough technologically advanced infrastructure to do so efficiently. Lesser-developed or peripheral countries tend to consist of relatively less fossil fuel based technologies and capital-intensive production. Thus, when excluding the most-developed countries (see description of the countries included in the present analyses), one would expect level of development to be positively associated with emissions per unit of GDP.

4. Gross domestic investment as percentage of total GDP represents the level of domestic investment in fixed assets plus net changes in inventory levels.[7] These data are obtained from the World Bank (2005). Controlling for domestic investment allows for a more rigorous assessment of the effects of foreign investment on both outcomes. Some scholars also suggest that domestically-controlled manufacturing is likely to be less environmentally harmful and more beneficial for domestic development than foreign-controlled manufacturing (e.g. Jorgenson 2006a; Kentor 2001). Partly through effective pressures by local organizations and communities, domestic investors and firms are more likely than transnational firms and foreign capital to invest in "greener" methods of production (Young 1997), and profits derived from domestic investment are more likely than profits from foreign investment to be reinvested locally (e.g. Kentor and Boswell 2003).

5. Manufacturing as percentage of total GDP controls for the extent to which a domestic economy is manufacturing-based. These data are gathered from the World Bank (2005). Including this measure allows us to assess the extent to which the transnational organization of production in the context of secondary sector foreign investment dependence contributes to higher total emissions and emissions per unit of production, net of the relative scale of the manufacturing sector in host economies.

6. Exports as percentage of total GDP controls for the extent to which a country is integrated into the international trading system. These data, which I log (ln) to correct for excessive skewness, are gathered from the World Bank (2005). I refer to this variable as a measure of export intensity, and other scholars treat export intensity as an indicator of economic globalization (e.g. Schofer and Hironaka 2005).

While the potential environmental impacts of export intensity and other characteristics of international trade are not the focus of the current study, recent analyses show a positive association between export intensity and total carbon dioxide emissions (e.g. Jorgenson 2007b). A common partial explanation for these findings is that in order to be relatively competitive in the world-economy, trade and other forms of economic globalization create added pressures for less-developed countries to lower environmental standards for export-oriented production (e.g. Jorgenson and Kick 2006; Schofer and Hironaka 2005).

7. Urban population as percentage of total population controls for a country's level of urbanization. I obtain these data from the World Bank (2005). Prior cross-sectional and panel analyses reveal positive associations between urbanization and a variety of environmental outcomes, including the total and per capita ecological footprints of nations (Jorgenson 2004; York et al. 2003) as well as the emission of carbon dioxide (Jorgenson 2007b) and other noxious gases (York and Rosa 2006).

8. Level of democracy/autocracy is used as a measure of democratization.[8] These data, which I gathered from the World Resources Institute, are indexed on a scale from -10 to +10. A score of +10 indicates a strongly democratic state; a score of -10 indicates a strongly autocratic state. A fully democratic government has three essential elements: fully competitive political participation, institutionalized constraints on executive power, and guarantee of civil liberties to all citizens in their daily lives and in political participation. A fully autocratic system sharply restricts or suppresses competitive political participation. The chief executives are chosen by an elite group and exercise power with few institutionalized constraints. The World Resources Institute obtains these data from the *Polity IV Project*.[9] Both ecological modernization theory and political modernization theory assert that democratization can lead to environmental reforms and more sustainable production processes because it creates conditions in which concerned groups and organizations influence policy development and behavior (e.g. Ehrhardt-Martinez et al. 2002; Mol 2001; Shandra et al. 2004).

Table 2 presents the descriptive statistics and bivariate correlations for all variables included in the reported analyses.[10]

Results and Discussion

Findings for the analyses of both outcomes are provided in Table 3. I report the results of two models for each outcome. Model A consists of secondary sector foreign direct investment stocks as % GDP, total population, GDP per capita, domestic investment as % GDP, and manufacturing as % GDP. Model B also includes exports as % GDP, urban population as % total population, and democratization. Elsewhere I estimate additional models for both outcomes that consist of all predictors in Model A as well as one of the three additional predictors in Model B. Results of these additional analyses are very consistent with those reported in Model B and available upon request. The reported analyses include unstandardized coefficients flagged for statistical significance, standard errors, and overall r-square values.[11]

Results indicate that secondary sector foreign investment as % GDP is positively associated with both total carbon dioxide emissions and emissions per unit of production. These findings, which hold across all reported and unreported models, support ecostructural theorization concerning the environmental impacts of the transnational organization of production in the context of foreign investment dependence (e.g. Jorgenson 2006a; Jorgenson et al. forthcoming; Kentor and Grimes 2006) as well as assertions in the burgeoning globalization and the environment literature about the outsourcing of production-based environmental costs by transnational firms, particularly those headquartered in more-developed countries (e.g. Frey 2003, Hornborg et al. 2007). More specifically, it appears that transnational firms and foreign capital are more likely to invest in highly polluting *and* ecologically inefficient manufacturing processes and facili-

Table 2. Descriptive Statistics and Correlations (N=530)

	Mean	Std Dev	Min	Max									
Total Carbon Dioxide Emissions (ln)	10.466	1.704	5.963	15.061									
Carbon Dioxide Emissions per GDP (ln)	6.591	.721	4.300	8.743	.583								
Secondary Sector FDI stocks as % GDP (ln)	1.353	.642	.067	3.640	-.058	-.175							
Total Population (ln)	10.367	1.459	7.459	14.001	.809	.542	-.296						
GDP per capita (ln)	6.995	1.030	5.121	8.943	.172	-.260	.386	-.358					
Domestic Investment as % GDP	22.692	5.981	6.150	43.920	.256	.184	.172	.059	.214				
Manufacturing as % GDP	18.655	6.614	3.330	39.120	.425	-.049	.181	.150	.532	.374			
Exports as % GDP (ln)	2.892	.646	1.144	4.558	-.313	-.065	.471	-.528	.183	.345	-.063		
Urban Population as % Total Population	44.082	20.724	5.000	88.400	.235	-.125	.259	-.235	.847	-.039	.416	.025	
Democratization	3.220	6.066	-9.000	10.000	-.051	-.177	-.023	-.261	.370	.053	.114	.112	.346

Table 3. Unstandardized Coefficients for the Regression of Carbon Dioxide Emissions on Secondary Sector Foreign Investment and other Selected Independent Variables: Fixed Effects Model Estimates with AR[1] correction for 3 to 26 Observations on 37 Less-Developed Countries, 1975-2000 (N=520)

	Total Emissions		Emissions per GDP	
	Model A	Model B	Model A	Model B
Secondary Sector FDI stocks as % GDP (ln)	.096**	.072**	.045*	.037#
	(.030)	(.028)	(.026)	(.025)
Total Population (ln)	.832**	.782**	.453**	.455**
	(.037)	(.035)	(.052)	(.055)
GDP per capita (ln)	.357**	.198**	.262**	.280**
	(.051)	(.052)	(.073)	(.075)
Domestic Investment as % GDP	.001	.002	-.001	-.001
	(.002)	(.002)	(.002)	(.001)
Manufacturing as % GDP	.007*	.006*	-.001	-.001
	(.003)	(.003)	(.003)	(.003)
Exports as % GDP (ln)		.063*		.067**
		(.033)		(.027)
Urban Population as % Total Population		.023**		-.005
		(.003)		(.005)
Democratization		.002		-.001
		(.002)		(.002)
Constant	-.960**	-.527**	.024	.031
	(.048)	(.048)	(.031)	(.033)
R^2 Overall	.864	.875	.207	.248

Notes: #p<.10 *p<.05 **p<.01; standard errors are in parentheses

ties, related transportation equipment, and power generation techniques in less-developed countries.

Total population is positively associated with both outcomes, and the positive effect on total emissions supports theorization and prior research in the structural human ecology tradition (e.g. Dietz and Rosa 1997). While including total population in the analyses of emissions per unit of GDP lacks direct theoretical justification, it allows for a more rigorous assessment of the impact of foreign investment. Moreover, the positive effect of total population on the second outcome points to a need for future theorization and corresponding research to explicitly consider why less-developed countries with larger populations tend to be relatively less ecoefficient.

Like population size, and consistent with prior research (e.g. Jorgenson 2007b; Roberts et al. 2003), level of development (GDP per capita) is positively associated with both total emissions and emissions per unit of production. More-developed countries possess the economic power and resources to consume vast amounts of resources, including fossil fuels, which contributes to total levels of carbon dioxide emissions (e.g. Chase-Dunn 1998). Considering that the sample is restricted to countries below the highest quartile of economic development, the positive effect of GDP per capita on emissions per unit of production is to be expected.[12] Semiperipheral or middle-developed countries tend to possess enough fossil fuel dependent technologies to compete in the global economy but lack technological infrastructure to do so as efficiently as more-developed countries (Roberts et al. 2006). Consistent with prior studies of investment and the environment (e.g. Kentor and Grimes 2003), the effect of domestic investment on both outcomes is non-significant.

The relative scale of the manufacturing sector is positively associated with total emissions, but the effect of manufacturing as % GDP on emissions per unit of production is non-significant. Coupled with the positive effect of secondary sector foreign investment on both outcomes, these findings illustrate the importance of and sociological relevance in considering the environmental impacts of both the transnational organization of production and the relative scale of production. While both contribute to overall carbon dioxide emissions, the results indicate that relative ecoefficiency is not necessarily affected by the size of the manufacturing sector per se, but is indeed partly a function of the organizational control and ownership of production. Indeed, future research would do well to more closely investigate how and why the size and organization of economic sectors impact various environmental outcomes differently in terms

of scale, relative ecoefficiency, and intensity (e.g. per capita emissions).

Exports as % GDP is positively associated with both outcomes, which corresponds with prior studies of carbon dioxide emissions (e.g. Schofer and Hironaka 2005). The globalization of trade creates added pressures for less-developed countries to lower environmental standards for export-oriented production (Jorgenson 2006c), and a common held assumption is that this is a prerequisite for success in the world-economy. Urban population is also positively associated with total emissions, but its effect on relative ecoefficiency is non-significant. In many less-developed countries, manufacturing is concentrated in urban areas, and the latter also tend to consume higher amounts of fossil fuels for transportation and power generation. Turning to the final predictor included in the analyses, the effect of democratization on both emissions per unit of production and total emissions is non-significant. Like other studies of environmental degradation in less-developed countries (e.g. Jorgenson and Burns 2007), the current analyses underscore the need for social scientists working in the political modernization and ecological modernization traditions to better articulate the structural conditions in which democratization can benefit the environment at a more macro level.

Conclusion

This study contributes to the growing sociological literature concerning the environmental impacts of the transnational organization of production in the context of foreign investment dependence. Foremost, the analyses of less-developed countries from 1975-2000 indicate that secondary sector foreign direct investment is positively associated with total carbon dioxide emissions and carbon dioxide emissions per unit of production. Thus, in general, transnationally controlled manufacturing within less-developed countries is relatively less ecoefficient and also contributes to the overall scale of environmental degradation. Considering that OLS fixed effects panel regression was used to estimate the tested models, we can place an even greater level of confidence in the validity of these inferences. Additional results are quite consistent with prior research in the structural human ecology tradition as well as different political-economic perspectives, particularly treadmill of production theory and world-systems analysis. Most notably, population size, level of development, and export intensity are all positively associated with both outcomes. Coupled with the positive effects of foreign investment, these findings do indeed point to the importance in considering both human ecological and political-economic factors when investigating the environmental impacts of human activities and related structural conditions.

The next steps in this particular research agenda are at least fourfold. First, I will investigate the possible relationships between foreign investment in manufacturing and both total and per unit of production emissions of greenhouse gases and air pollutants other than carbon dioxide gas as well as industrial organic water pollution intensity. The recent availability of cross-national panel data for carbon monoxide emissions, nitrogen oxides emissions, methane emissions, volatile organic compound emissions, and organic water pollution will allow for the use of more rigorous quantitative methods similar to those employed in the current study. Another future step in this research will involve investigating the extent to which primary sector foreign investment contributes to relevant forms of environmental degradation and related outcomes, including deforestation, loss of biodiversity, and the use of synthetic fertilizers and pesticides in agri-industrial production.[13] I also plan to compare the environmental impacts of both primary and secondary sector foreign investment in less-developed countries and developed countries. Lastly, using newly-available data I will collaborate with a colleague in Vilnius, Lithuania to study the environmental impacts of foreign investment and other forms of world-economic integration for Eastern European countries. Recently, the latter have experienced rapid increases of structural integration into the world-economy and thus provide a unique and rather important avenue for comparative analyses in this tradition.

Endnotes

1. E-mail: akjorgen@chass.ncsu.edu
2. Adequate foreign investment stocks data for less-developed countries were unavailable at the time of the study to expand the analyses to the post 2000 period.
3. The primary sector consists of agriculture, mining, forestry, and other related activities. The secondary sector consists of all manufacturing activities as defined by the SITC classification code, and in the current study I use the terms secondary sector foreign investment and foreign investment in manufacturing interchangeably.
4. Elsewhere, I tested all reported models with both generalized least squares random effects [RE] regression and Prais-Winston regression with panel corrected standard errors. While Hausman test statistics indicate that FE models are more appropriate than RE models for the current study, results of these additional analyses do not vary substantively from the reported findings and are available from the author upon request.
5. At the time of the analyses there were no less-developed countries in which data were available for all variables for just 2 time points, which explains why the unbalanced panel dataset consists of cases with between three to 26 observations.
6. Using appropriate diagnostics, I determined that the sample used in the current study does not include any overly influential cases.
7. I would prefer measures of domestic investment for only the manu-

facturing sector. However, those types of data were unavailable at the time of this study.

8. Elsewhere I use Vanhanen's (1997) lesser known index of democracy, which consists of two components: electoral competition and popular participation. Findings for these additional analyses are very similar to those reported in the current study and available upon request.
9. The *Polity IV Project* is available online at www.bsos.umd.edu/cidcm/inscr/polity/index.htm.
10. Due to length limitations, scatterplots for the bivariate relationships are not reported. However, they are available from the author upon request.
11. In a series of unreported diagnostic analyses I determined that the reported findings are not biased due to multicollinearity.
12. The sizable differences in the r-square values for the two outcomes are primarily a function of the overall effect of total population on scale outcomes, in this case total carbon dioxide emissions. In a model of total emissions that includes only total population as a predictor, the overall r-square value is close to .700. This is quite common with prior research, most notably works in the structural human ecology tradition (e.g. Rosa et al. 2004).
13. While it is beyond the scope of the current study's primary objectives, prior cross-sectional research has shown that if developed countries are included in the analyses, the effect of GDP per capita on emissions per unit GDP is somewhat curvilinear, but theoretical explanations tend to differ (e.g. Roberts and Grimes 1997; Ehrhardt-Martinez et al. 2002).
14. Preliminary findings show a positive association between primary sector foreign investment and pesticide use intensity in less-developed countries (Jorgenson 2007a).

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