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DOES FOREIGN INVESTMENT HARM THE AIR WE BREATHE AND THE WATER WE DRINK?

A Cross-National Study of Carbon Dioxide Emissions and Organic Water Pollution in Less-Developed Countries, 1975 to 2000

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This research investigates the extent to which the transnational organization of production in the context of foreign investment dependence affects the environment in less developed countries. Drawing from the theory of foreign investment dependence, the author tests two hypotheses: (a) Foreign investment dependence in the manufacturing sector is positively associated with carbon dioxide emissions in less developed countries, and (b) foreign investment dependence in the manufacturing sector is positively associated with the emission of organic water pollutants in less developed countries. Findings for the ordinary least squares fixed effects panel regression analyses confirm both hypotheses, providing support for the theory. Other results correspond with prior research in the political-economic and structural human ecology traditions.

Keywords: *globalization; foreign investment dependence; carbon dioxide emissions; water pollution; environmental degradation*

Research concerning the environmental impacts of the world economy has become commonplace in macrosociology and other social sciences. Within this overall body of literature, a growing number of social scientists draw from the longstanding theory of foreign investment dependence (e.g., Bornschier & Chase-Dunn, 1985) to theoretically articulate and empirically chart how the transnational organization of production contributes to different forms of environmental degradation (e.g., Grimes & Kentor, 2003; Jorgenson, Dick, & Mahutga, in press). The importance of considering the relationship between foreign investment dependence and the environment is underscored by the recent upswing in the globalization of foreign investment (Chase-Dunn & Jorgenson, 2006), the intensification of global commodity production (e.g., Talbot, 2004), and increases in different forms of environmental degradation, particularly within less developed countries (e.g., Redclift & Sage, 1998).

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In the current study, I help to advance this area of social scientific inquiry. I do so by investigating the extent to which the transnational organization of production in the context of foreign investment dependence contributes to the emission of carbon dioxide gas and the emission of industrial organic water pollutants. These two outcomes have serious consequences for the environment and health of human and nonhuman populations. Using fixed effects (FE) ordinary least squares (OLS) panel regression analyses for less developed countries, I test two hypotheses: (a) Foreign investment dependence in the manufacturing sector is positively associated with carbon dioxide emissions in less developed countries, and (b) foreign investment dependence in the manufacturing sector is positively associated with the emission of industrial organic water pollutants in less developed countries. The tested models include a variety of theoretically relevant controls, including population size, level of economic development, domestic investment, relative size of the manufacturing sector, urbanization, and export intensity. Findings for the analyses confirm both hypotheses, providing support for the theory of foreign investment dependence. Additional results are consistent with prior research in structural human ecology (e.g., Dietz & Rosa, 1997; York, Rosa, & Dietz, 2003) and different political-economy traditions (e.g., Jorgenson & Burns, in press; Roberts, Grimes, & Manale, 2003).

In the next section, I review theorization and prior research on foreign investment dependence. I pay particular attention to the burgeoning area of literature on the relationship between foreign investment dependence and the environment, including some of its limitations, which lead to the formalization of the two hypotheses tested in the current study. Next, I describe the quantitative methods used to test the hypotheses as well as the two samples and all variables included in the analyses. This is followed by the presentation and discussion of the findings. In the concluding section, I summarize the key results of the study as well as their theoretical significance, and I outline the future steps of this research agenda.

Foreign Investment Dependence, Air Pollution, and Water Pollution

The literature on foreign investment dependence has a rather broad and deep history in macrosociology and other comparative social sciences. In general, the theory of foreign investment dependence asserts that the accumulated stocks of foreign investment make a less developed country more vulnerable to different global political-economic conditions, often leading to negative consequences for domestic populations within investment-dependent nations (Bornschier & Chase-Dunn, 1985; Chase-Dunn, 1975). These structural processes and outcomes are partly maintained and reproduced by the stratified interstate system (Chase-Dunn, 1998). The vast majority of studies that test the theory of foreign investment dependence assess the impacts of foreign investment on economic development, domestic income inequality, overurbanization, and other social outcomes (e.g., Alderson & Nielson, 1999; Bornschier, Chase-Dunn, & Rubinson, 1978; Bradshaw, 1987; Bussmann, De Soysa, & Oneal, 2005; Dixon & Boswell, 1996a, 1996b; Firebaugh, 1996; Kentor, 1998, 2001; Kentor & Boswell, 2003; London & Smith, 1988; London & Williams, 1990; Wimberley & Bello, 1992). However, social scientists have begun to investigate the extent to which different forms of environmental degradation within less developed countries are a function of the transnational organization of production in the context of foreign investment dependence (e.g., Grimes & Kentor, 2003; Jorgenson, 2006a, 2006b, 2007a; Jorgenson et al., in press; Kentor & Grimes, 2006).

Through the influence of global governance institutions (McMichael, 2004), coupled with the perceived threat of capital flight (Wallerstein, 2005), less developed countries often focus on creating attractive business conditions for foreign investors and transnational corporations. These attractive business conditions include lower domestic environmental regulations than developed countries (e.g., Clapp, 1998; Frey, 2003), and less developed countries are less likely than developed countries to ratify international environmental treaties (J. T. Roberts, 1996; T. Roberts, Parks, & Vasquez, 2004). With these emergent political-institutional conditions, many social scientists argue that a large proportion of foreign investment in less developed countries finances highly polluting, ecologically inefficient, and labor-intensive manufacturing processes and facilities outsourced from developed countries (e.g., Clapp, 1998; Jorgenson, 2006b; T. Roberts, Grimes, & Manale, 2006). Moreover, power generation techniques and facilities used by transnational corporations and domestic populations in many less-developed countries are considerably less ecoefficient (Kentor & Grimes, 2006). These activities contribute to the emission of carbon dioxide as well as other noxious gases and air pollutants. Considering that carbon dioxide emissions are the largest anthropogenic contributor to global warming and climate change (e.g., Houghton et al., 2001; National Research Council, 1999; World Resources Institute, 2005), investigating the relationship between foreign investment dependence and carbon dioxide emissions is indeed critical.

In addition to production equipment and power generation facilities, the transportation vehicles used by foreign-owned manufacturing enterprises in less developed countries for the movements of goods and labor are more likely to be outdated and energy inefficient (Grimes & Kentor, 2003). Although carbon monoxide emissions can be reduced if transportation vehicles and manufacturing equipment with internal combustion engines have catalytic converters—a common emission suppression device—the latter type of device does not help to reduce carbon dioxide emissions. The ratio of oxygen to fuel that enables catalytic converters to work more effectively in reducing carbon monoxide and other noxious gases can actually increase the emission of carbon dioxide gas (Marshall, 1977: Silver, Sawyer, & Summers, 1992). Carbon dioxide emissions resulting from manufacturing, power generation, and forms of transportation can be reduced only through the overall reduction of fossil fuel use or possibly through the reduction in fossil fuel use per unit of production (e.g., International Energy Agency, 2001; Rosenfeld, Kaarsberg, & Romm, 2000). However, many social scientists argue that the potential environmental benefits of reduction in fossil fuel use per unit of production are generally outpaced by the overall scale of fossil fuel use in manufacturing, transportation, and other related human activities (e.g., Jorgenson, 2006d; York & Rosa, 2003; York, Rosa, & Dietz, 2004).

Besides carbon dioxide emissions and other air pollutants, different manufacturing activities controlled by foreign capital contribute to water pollution as well (Jorgenson, 2006b). The use of organic materials in different productive activities often results in waste products that end up as water pollutants. Many of these organic materials are highly toxic and capable of remaining in the environment for long periods of time. This is most common with organic chemicals that are resistant to biodegradation and decomposition (Eckenfelder, 2000). More specifically, a large portion of industrial organic water pollutants are traced to the environmentally unfriendly processing of industrial chemicals, steelmaking, pulp and paper manufacturing, food processing, and textile production (e.g., World

Resources Institute, 2005). Water pollution from steel production results from the leaching of electric arch furnace dust into ground water and the dispersing of water used to cool coke after it has finished baking (Andres & Irabien, 1994). Food-processing plants are a possible source of disease causing bacteria, parasites, and viruses, and these processing plants often have inadequate waste treatment facilities (Manahan, 2005). Clothing manufacturing involves a variety of dyes and fixers, some of which become waste that ends up in local water tables (Frey, 2006). Pulp and paper manufacturing contribute to some of the most common organic water pollutants, including lost cellulose fiber, starch and hemicellulose, and carbohydrate (Stanley, 1996). Moreover, different synthetic and natural organic chemicals are used to produce plastics, pesticides, medicines, paint pigments, and other commonly used products (Manahan, 2005). Relaxed or nonexistent environmental policies and regulations, coupled with outdated production and waste-handling equipment, often lead to these various forms of industrial organic pollutants accumulating in bodies of water used by domestic populations for subsistence purposes (World Resources Institute, 2005).

The human health and environmental consequences of industrial water pollution are significant. Exposure to organic pollutants in water is associated with various types of cancer, birth defects, and spontaneous abortion (Cadbury, 2000; Levallois et al., 1998; McGinn, 2000). Moreover, organic pollutants tend to accumulate in the fatty tissue of mammals as they move up the food chain (Czub & McLachlan, 2004). When these toxins accumulate in the fatty tissues of women, they can be transferred to infants and young children through breast feeding, which leads to acute health problems for the latter, sometimes resulting in death (Burns, Kentor, & Jorgenson, 2003). When added to water, some organic chemicals from manufacturing processes stimulate oxygen consumption by decomposers. This increased oxygen consumption can deplete the dissolved oxygen level, and if re-aeration is inadequate, invertebrate animals and fish die from lack of oxygen (e.g. Stanley, 1996). Organic water pollutants can also kill fish by disrupting the pH balance of water and by building up to toxic levels (Miller, 2000).

Although recent studies link both carbon dioxide emissions and industrial organic water pollutants to dependence on foreign investment, these analyses have limitations that question their overall validity. For example, prior research on foreign investment and either outcomes are cross-sectional by design (e.g., T. Roberts et al., 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 & Kentor, 2003; Jorgenson, 2006b; Shandra, London, Whooley, & Williamson, 2004). Although researchers typically use them because of data availability restrictions, cross-sectional models are stationary in character, which limits causal inferences (Twisk, 2003). Static score panel models, also known as panel regression with the lagged dependent variable, are relatively limited in dealing with unmeasured time-invariant variables (Wooldridge, 2002). Indeed, more powerful panel regression methods exist that effectively handle these and many other important issues, such as autocorrelation.

Another limitation in this existing body of literature, particularly prior research on carbon dioxide emissions, is the use of foreign investment measures that combine investment in all economic sectors. Although sector-level measures of foreign investment were largely unavailable in the past, cross-national panel data have become increasingly available for both the secondary (i.e., manufacturing) and primary (e.g., agriculture, mining) sectors, and these measures are only moderately correlated at best (e.g., United Nations, 1992, 1994, 1996, 2000, 2003). Considering that theorization about the effects of foreign investment on carbon dioxide emissions and organic water pollutants focus on secondary sector activities, the use of more nuanced measures of investment, particularly measures of investment in the manufacturing sector, would lead to more valid hypothesis testing.[1] In the current study, I help to resolve such issues. Building on prior research and theorization, in the following analyses, I use more rigorous statistical methods and newly available panel data to test the following two hypotheses:

> H_1: Foreign investment dependence in the secondary sector is positively associated with carbon dioxide emissions in less developed countries.

> H_2: Foreign investment dependence in the secondary sector is positively associated with the emission of industrial organic water pollutants in less developed countries.

METHOD, SAMPLES, AND VARIABLES INCLUDED IN THE ANALYSES

FE Models With AR[1] Correction

To test the two hypotheses, I use STATA Version 9 software to estimate OLS FE models with a correction for first-order autocorrelation (i.e., AR[1] correction) (Frees, 2004; Hamilton, 2006; STATA, 2005). Autocorrelation is common with time series and panel models, and not correcting for this often leads to biased standard error estimates (Greene, 2000; Wooldridge, 2002).

In macrosociology as well as other comparative social sciences, OLS FE models are perhaps the most commonly used methods designed to correct for the problem of heterogeneity bias[2] (see 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 geographic region and natural resource endowments could affect environmental outcomes. Overall, this modeling approach is quite robust against missing control variables and closely approximates experimental conditions (Greene, 2000; Hsiao, 2003). Also, and more important, the FE approach provides a stringent test of the current study's two hypotheses, given that the associations between secondary sector foreign investment and both outcomes are estimated net of all unmeasured between-country effects (e.g., Beckfield, 2007).

Unbalanced Panel Data Sets

I include all less developed countries in which data are available for the dependent and independent variables for a minimum of 2 years 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, 2000, 2005). Using this quartile

Table 1: Countries Included in the Analyses

Argentina [a,b]
Bangladesh [a,b]
Benin [a]
Brazil [a,b]
Cameroon [a,b]
China [a,b]
Colombia [a,b]
Costa Rica [a,b]
Dominican Republic [a,b]
Ecuador [a,b]
El Salvador [a,b]
Ghana [a]
Haiti [a]
Honduras [a,b]
India [a,b]
Indonesia [a,b]
Kenya [a,b]
Malaysia [a,b]
Mexico [a,b]
Morocco [a,b]
Nepal [a,b]
Nicaragua [a]
Nigeria [a,b]
Pakistan [a,b]
Panama [a,b]
Paraguay [a]
Peru [a,b]
Philippines [a,b]
Rwanda [a]
Senegal [a,b]
Sri Lanka [a,b]
Thailand [a,b]
Turkey [a,b]
Uganda [a]
Venezuela [a,b]
Vietnam [a]
Zimbabwe [a,b]

a. Included in the carbon dioxide emissions analyses.
b. Included in the organic water pollution analyses.

classification in identifying possible cases is common in prior studies, especially those restricted to less developed countries (e.g. Jorgenson, 2006b, 2006c).

For the carbon dioxide emissions analyses, the number of observations per country range from 2 to 25 for 37 less developed countries. Overall, this results in an unbalanced panel data set with a sample size of 519. Using the same general criteria in gathering data for the organic water pollution analyses, I analyze an unbalanced panel data set with a sample of 350, which consists of data for 29 less developed countries from 1980 to 2000. Unlike carbon dioxide emissions, national-level estimates of organic water pollution are unavailable for years prior to 1980. For each country, the number of observations range from 2 to 20. Table 1 lists the countries included in the two sets of analyses.[3]

Dependent Variables

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 manufacturing 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.

The second dependent variable is total organic water pollutant emissions per day. These data are measured in kilograms and by biochemical oxygen demand, which refers to the amount of oxygen that bacteria in water will consume in breaking down waste. In particular, the measures include water pollutants from manufacturing activities as defined by the two-digit divisions of the International Standard Industrial Classification revision.[4] Overall, this consists of organic water pollutants from the manufacturing of primary metals, paper and pulp, chemicals, food and beverages, stone, ceramics, glass, textiles, wood, and manufactured goods included in the two divisions of classification labeled as "Other" manufactured goods (Divisions 38 and 39). These data, which I log (ln) to correct for excessive skewness, are gathered from the World Resources Institute (2005).

Key Independent Variable

The key independent variable used in all reported analyses is the accumulated stocks of secondary sector foreign direct investment (FDI) as percentage of total gross domestic product (GDP). This variable is used to test the two hypotheses. I log these data (ln) to minimize 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 & Nielson, 1999; Dixon & Boswell, 1996a; Kentor & Boswell, 2003; Jorgenson, 2006b). Foreign direct investment stocks data are obtained from United Nations' (1992, 1994, 1996, 2000, 2003) *World Investment Directories* and the Organisation for Economic Co-Operation and Development's (OECD, 2001) *International Direct Investment Statistics Yearbook*. Total GDP data are measured in 1995 US dollars (World Bank, 2000, 2005). The measures of secondary sector foreign direct investment stocks consist of investment in the following manufacturing activities (United Nations, 1992, 1994, 1996, 2000, 2003; OECD, 2001):

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

Nonmetallic mineral products
Metal and metal products
Machinery and equipment
Electrical and electronic equipment
Precision instruments
Motor vehicles and other transport equipment
Other manufacturing
Recycling

Additional Independent Variables

Total population is measured in thousands and logged (ln) to correct for excessive skewness. These data are obtained from the World Bank (2000, 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. Of particular relevance for the current study, controlling for population is critical when investigating environmental outcomes measured by scale (e.g., total emissions) rather than per person (e.g., per capita emissions) or per unit of production (e.g., emissions per unit of GDP). Thus, total population is a very common statistical control in this type of cross-national investigation (e.g., Burns, Davis, & Kick, 1997; Dietz & Rosa, 1997; York et al., 2003).

GDP per capita is included as a control for level of economic development. These data, which I gather from the World Bank (2000, 2005), are measured in 1995 U.S. dollars and logged (ln) to correct for skewness. Like total population, level of development is the most common statistical control in cross-national research on environmental outcomes measured by scale, and prior research on both carbon dioxide emissions and industrial organic water pollutants consistently show a positive association between these outcomes and level of development (e.g., Jorgenson, 2006b; Rosa, York, & Dietz, 2004).

Gross domestic investment as percentage of total GDP represents the level of domestic investment in fixed assets plus net changes in inventory levels. I obtain these data from the World Bank (2000, 2005). I would prefer measures of domestic investment for only the manufacturing sector. However, those types of data were unavailable at the time of this study. Controlling for domestic investment allows for a more rigorous assessment of the effects of foreign investment on both outcomes. Of substantive relevance, some scholars suggest that domestically controlled manufacturing is likely to be less environmentally harmful than foreign-controlled manufacturing (e.g., Jorgenson, 2006a). 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).

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 (2000, 2005). Of particular sociological relevance, including this control allows us to assess the extent to which the transnational organization of production in the context of secondary sector foreign investment dependence affects the environment, net of the relative size of the manufacturing sector in host economies.

Exports as percentage of total GDP controls for the extent to which a country is integrated into the international trading system.[5] These data, which I log to minimize skewness (ln), are obtained from the World Bank (2000, 2005). Prior research on environmental outcomes treats this measure as an indicator of export intensity (e.g., Jorgenson, 2005, 2006c; Jorgenson & Burns, in press). Although the potential environmental impacts of export intensity and other aspects of international trade are not the focus of the current analyses, recent studies show a positive association between export intensity and carbon dioxide emissions (Schofer & Hironaka, 2005) as well as direct and indirect positive effects of trade dependence in the context of export commodity concentration on the emission of organic water pollutants in less developed countries[6] (Burns et al., 2003).

Urban population as a percentage of total population controls for a country's level of urbanization. These data are gathered from the World Bank (2000, 2005). Level of urbanization is a very common statistical control in cross-national research, and recent studies find positive associations between urbanization and a variety of environmental outcomes, including the total and per capita ecological footprints of nations (Jorgenson, 2003, 2004; Jorgenson, Rice, & Crowe, 2005; York et al., 2003) as well as the emission of noxious gases (e.g., York & Rosa, 2006).

Table 2 provides descriptive statistics, and Table 3 presents bivariate correlations for all variables included in the analyses. Note that two sets of statistics are reported in each table. The first set is for the sample included in the carbon dioxide emissions analyses, and the second set is for the sample included in the organic water pollution analyses.

RESULTS AND DISCUSSION

Results of the analyses are reported in the following two tables. I present and discuss the findings one outcome at a time, with a particular focus on the effects of secondary sector foreign investment stocks as percentage of GDP.[7] I report unstandardized coefficients (flagged for statistical significance), standard errors, R^2 within, R^2 between, and R^2 overall. R^2 within refers to the explained variation within cases, R^2 between quantifies the explained variation between cases, and R^2 overall refers to the overall explained variance in the tested model (Hamilton, 2006).

I test the same five models for both outcomes. The first model is treated as a baseline, consisting of secondary sector foreign investment stocks as percentage of GDP, total population, level of economic development (GDP per capita), and level of domestic investment as percentage of GDP. Models 2 through 4 consist of the variables included in the baseline model as well as one additional statistical control. The additional predictor in Model 2 is manufacturing as percentage of GDP. Exports as percentage of GDP is the additional statistical control in Model 3, and urban population as percentage of total population is the additional variable in Model 4. Model 5 is the most fully saturated of the tested models and consists of all seven independent variables.[8]

Table 4 presents the findings for the carbon dioxide emissions analyses. The effect of secondary sector foreign direct investment stocks as percentage of GDP is positive and statistically significant across all tested models. These results, which confirm the first hypothesis, support theorization concerning the environmental impacts of the transnational organization of production in the context of secondary sector foreign investment dependence. The temporal scope of the analyses as well as the increased sample size and use of more rigorous statistical

Table 2: Descriptive Statistics

Data Set for Carbon Dioxide Emissions Analyses (N = 519)				
	M	*SD*	*Min.*	*Max.*
Total carbon dioxide emissions (ln)	9.508	2.091	4.430	15.061
Secondary sector FDI stocks as % GDP (ln)	1.364	.641	.068	3.640
Total population (ln)	9.873	1.488	7.460	14.001
GDP per capita (ln)	6.724	1.007	5.121	8.943
Domestic investment as % GDP	20.718	6.737	6.150	43.920
Manufacturing as % GDP	17.224	7.228	3.330	40.720
Exports as % GDP (ln)	2.866	.630	.609	4.558
Urban population as % total population	37.480	20.111	3.200	88.400
Data Set for Organic Water Pollution Analyses (N = 350)				
	M	*SD*	*Min.*	*Max.*
Total organic water pollution (ln)	11.692	1.340	8.619	15.838
Secondary sector FDI stocks as % GDP (ln)	1.324	0.670	0.068	3.640
Total population (ln)	10.501	1.467	7.575	14.001
GDP per capita (ln)	7.082	1.019	5.121	8.943
Domestic investment as % GDP	23.489	5.704	6.150	43.920
Manufacturing as % GDP	19.337	6.556	4.570	39.120
Exports as % GDP (ln)	2.902	0.659	1.144	4.514
Urban population as % total population	45.353	21.010	7.800	86.880

NOTE: FDI = foreign direct investment; GDP = gross domestic product.

techniques further validates the efficacy of the theory, especially when examining environmental outcomes. In less developed countries, transnational manufacturing firms are more likely to finance and use highly polluting, ecologically inefficient production processes and machinery as well as transportation equipment and energy sources that contribute to the emission of carbon dioxide gas.

Both total population and level of economic development positively affect total carbon dioxide emissions, and the positive effects are statistically significant across all five models. These findings are quite consistent with structural human ecology theorization (e.g., Dietz & Rosa, 1994) and prior research on the total emission of carbon dioxide as well as other noxious gases and environmental outcomes (e.g., Burns et al., 1997; Rosa et al., 2004; Shi, 2003; York et al., 2003). The effect of domestic investment is nonsignificant, which corresponds with other studies of investment and greenhouse gas emissions (e.g., Grimes & Kentor, 2003; Jorgenson, 2006a; Kentor & Grimes, 2006). Manufacturing as percentage of GDP positively affects carbon dioxide emissions, but including this control only slightly tempers the positive effect of secondary sector foreign investment. Thus, when investigating the relationship between manufacturing activities and noxious gas emissions, one must consider both the relative scale of production as well as the organizational control of production in the secondary sector. Exports as percentage of GDP and urban population as percentage of total population are both positively associated with carbon dioxide emissions. Combined with the positive effect of secondary sector foreign investment, the effect of export intensity, which corresponds with prior studies (e.g., Schofer & Hironaka, 2005), illustrates how different structural aspects of the world economy have the potential to increase forms of environmental degradation, particularly in less developed countries

Table 3: Bivariate Correlations

Data Set for Carbon Dioxide Emissions Analyses (N = 519)							
	1	*2*	*3*	*4*	*5*	*6*	*7*
Total carbon dioxide emissions (ln)							
Secondary sector FDI stocks as % GDP (ln)	–.059						
Total Population (ln)	.810	–.297					
GDP per capita (ln)	.174	.385	–.354				
Domestic investment as % GDP	.255	.172	.058	.213			
Manufacturing as % GDP	.425	.181	.151	.532	.374		
Exports as % GDP (ln)	–.315	.471	–.530	.181	.345	–.063	
Urban population as % total population	.234	.260	–.236	.845	–.038	.415	.026
Data Set for Organic Water Pollution Analyses (N = 350)							
	1	*2*	*3*	*4*	*5*	*6*	*7*
Total organic water pollution (ln)							
Secondary sector FDI stocks as % GDP (ln)	–.197						
Total population (ln)	.897	–.360					
GDP per capita (ln)	–.187	.471	–.454				
Domestic investment as % GDP	.292	.171	.097	.099			
Manufacturing as % GDP	.394	.158	.143	.460	.318		
Exports as % GDP (ln)	–.444	.546	–.563	.246	.288	–.088	
Urban population as % total population	–.143	.333	–.301	.868	–.103	.387	.067

NOTE: FDI = foreign direct investment; GDP = gross domestic product.

(Foster, 2002; Jorgenson & Kick, 2006). The positive association between urban population and carbon dioxide emissions supports urban political-economic assertions. Many forms of production and transportation that generate emissions take place in urban regions, and these built environments often require higher levels of energy for the day-to-day activities of dense populaces (e.g., Evans, 2002; Jorgenson et al., 2005; Logan & Molotch, 1987).

Findings for the analyses of organic water pollution are reported in Table 5. The effect of secondary sector foreign investment stocks as percentage of GDP is positive and statistically significant across all tested models. This set of results, which corresponds with the carbon dioxide analyses, confirms the second hypothesis and provides additional support for the theorization concerning the environmental impacts of foreign investment dependence in manufacturing. In general, foreign-controlled manufacturing firms in less developed countries are more likely to use organic chemicals in different productive activities that often generate waste products, which end up as industrial water pollutants. Thus, the analyses reported in Tables 4 and 5 suggest that dependence on secondary sector foreign investment contributes to both air and water pollution in less developed countries.

Total population and level of development both positively affect level of organic water pollutants, and these positive effects are statistically significant across all five models. Like the carbon dioxide analyses, these findings lend support to structural human ecological theorization (e.g., Dietz & Rosa, 1994; York et al., 2003) about the overall environmental impacts of population and affluence as well as prior

Table 4: 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 2 to 25 Observations on 37 Less Developed Countries, 1975 to 2000 (N = 519)

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Secondary sector FDI stocks as % GDP (ln)	.108** (.030)	.097** (.030)	.091** (.030)	.094** (.029)	.076** (.029)
Total population (ln)	.876** (.041)	.873** (.041)	.845** (.042)	.822** (.040)	.804** (.039)
GDP per capita (ln)	.295** (.061)	.280** (.062)	.274** (.061)	.173** (.060)	.160** (.060)
Domestic investment as % GDP	.002 (.002)	.002 (.002)	.003 (.002)	.003 (.002)	.003 (.002)
Manufacturing as % GDP		.007* (.003)			.006* (.003)
Exports as % GDP (ln)			.123** (.034)		.068* (.033)
Urban population as % total population				.024** (.003)	.022* (.003)
Constant	–.915** (.048)	–.886** (.048)	–.792** (.050)	–.583** (.048)	–.511** (.049)
R^2 within	.943	.943	.945	.949	.950
R^2 between	.836	.838	.844	.886	.899
R^2 overall	.832	.834	.841	.880	.892

NOTE: Standard errors are in parentheses. FDI = foreign direct investment; GDP = gross domestic product.
*$p < .05$. **$p < .01$ (two-tailed tests).

Table 5: Unstandardized Coefficients for the Regression of Organic Water Pollution on Secondary Sector Foreign Investment and Other Selected Independent Variables: Fixed Effects Model Estimates With AR[1] Correction for 2 to 20 Observations on 29 Less Developed Countries, 1980 to 2000 ($N = 350$)

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Secondary Sector FDI stocks as % GDP (ln)	.101** (.037)	.092* (.038)	.097** (.037)	.101** (.038)	.091* (.038)
Total population (ln)	.773** (.048)	.775** (.048)	.767** (.049)	.773** (.049)	.768** (.050)
GDP per capita (ln)	.478** (.079)	.457** (.081)	.470** (.080)	.485** (.093)	.472** (.094)
Domestic investment as % GDP	–.003 (.002)	–.003 (.002)	–.002 (.002)	–.003 (.002)	–.003 (.002)
Manufacturing as % GDP		.006 (.004)			.005 (.004)
Exports as % GDP (ln)			.034 (.047)		.030 (.049)
Urban population as % total population				.001 (.005)	–.002 (.005)
Constant	.099* (.049)	.137** (.050)	.110* (.049)	.093 (.051)	.126* (.052)
R^2 within	.967	.967	.967	.966	.967
R^2 between	.840	.850	.842	.845	.863
R^2 overall	.828	.838	.830	.833	.851

NOTE: Standard errors are in parentheses. FDI = foreign direct investment; GDP = gross domestic product.
$*p < .05$. $**p < .01$ (two-tailed tests).

political-economic studies of organic water pollution intensity (e.g., Burns et al., 2003; Jorgenson, 2006b). The effects of all remaining statistical controls are nonsignificant. The nonsignificant effects of domestic investment and manufacturing as percentage of GDP, combined with the positive effect of secondary sector foreign investment, further highlight the importance in considering the potential environmental impacts of the transnational organization of production as well as the relative scale of production in the secondary sector. Coupled with the results of the carbon dioxide analyses, the nonsignificant effects of both exports as percentage of GDP and urban population as percentage of total population on the emission of organic water pollutants suggest that the impacts of international trade and urbanization are far from identical across different environmental outcomes. Indeed, recent studies of deforestation (e.g., Jorgenson, 2006c; Rudel, 2005), the ecological footprints of nations (e.g., Jorgenson & Burns, in press), and different greenhouse gas emissions (e.g., Kentor & Grimes, 2006; Shandra et al., 2004; York & Rosa, 2006) yield similar results.

CONCLUSION

This study contributes to the growing social scientific literature on the potential environmental impacts of foreign investment dependence, particularly for less developed countries (e.g., Grimes & Kentor, 2003; Jorgenson, 2006a, 2006b). The recent upswing in the structural globalization of foreign investment (Chase-Dunn, Kuwano, & Brewer, 2000; Chase-Dunn & Jorgenson, 2006), the broadening and deepening of global commodity chains (e.g., Talbot, 2004), the intensifying global treadmill of production (e.g., Gould, Pellow, & Schnaiberg, 2004; York, 2004), and the increasing scale of different forms of environmental degradation within less developed countries (e.g., Jorgenson & Kick, 2006; World Resources Institute, 2005) all highlight the importance of this research. Findings for the OLS FE panel regression analyses of less developed countries indicate that foreign investment dependence in manufacturing is positively associated with total carbon dioxide emissions (37 less developed countries, 1975 to 2000) and the emission of organic water pollutants (29 less developed countries, 1980 to 2000). These findings hold, net of the effects of other theoretically relevant factors. Thus, foreign investors and transnational firms in less developed countries are more likely to invest in manufacturing processes, related transportation vehicles, and power generation techniques that are highly polluting for both air and water. Indeed, these outcomes have serious consequences for the environment and health of human and nonhuman populations.

Other results of this study correspond with prior research in structural human ecology (e.g., Dietz & Rosa, 1997; Rosa et al., 2004; York et al., 2003) and different political-economic traditions (e.g., Burns et al., 1997; Jorgenson, 2003; Jorgenson & Burns, in press). Population size and level of development are both positively associated with carbon dioxide emissions and the emission of organic water pollutants, whereas the effect of domestic investment is nonsignificant in all tested models. Level of urbanization, the relative size of the manufacturing sector, and level of export intensity are all positively associated with carbon dioxide emissions, whereas their effects on the emission of organic water pollutants are nonsignificant. Besides emphasizing the importance in taking a more nuanced approach to studying human-caused environmental degradation, the results of this study indicate that although the transnational organization of production in the context of secondary sector foreign investment dependence contributes to both air and water pollution in less developed countries, the effects of other political-economic and social structural factors on different types of environmental degradation are far from monolithic. With the increasing availability of cross-national data for various environmental outcomes, researchers would do well to more closely examine the similarities and differences in how different characteristics of the world economy as well as other social structural factors contribute to diverse forms of environmental degradation.

The next steps in this research agenda are fourfold. First, I will extend my analyses of secondary sector foreign investment in less developed countries to other forms of noxious gas emissions, including carbon monoxide, nitrogen oxides, methane, and the emission of nonmethane volatile organic compounds. Like carbon dioxide emissions and organic water pollutants, these other forms of emissions are all partly a function of secondary sector activities. Second, I will also investigate if foreign-controlled manufacturing is relatively more or less “ecoefficient.” This will involve assessing the effects of secondary sector foreign investment on emissions per unit of production for different types of air pollutants. Third, I plan to investigate the possible relationships between primary sector foreign investment and particular forms of environmental degradation in less developed countries, including deforestation, unsustainable levels of pesticide use and fertilizer use, and loss of biodiversity. In the fourth step, I will conduct in-depth case studies to better understand the complex “on the ground” dynamics involved in the statistical relationships revealed by the cross-national analyses. Besides expanding the social scientific literature on human causes and consequences of environmental degradation, it is my hope that this overall body of research will assist in the development and implementation of more effective domestic and international policies to help reduce the environmental impacts of the transnational organization of production, particularly in less developed countries.

NOTES

1. In a recent study, Jorgenson (2007b) investigates the effects of primary sector investment on growth in carbon dioxide emissions resulting from agricultural production in less developed countries. Although the results indicate that foreign investment in the primary sector is associated with higher levels of growth in emissions from primary sector activities, it is critical to note that in general, carbon dioxide emissions from agricultural production are only a very small portion of overall anthropogenic carbon dioxide emissions (World Resources Institute, 2005).

2. Elsewhere, I tested all reported models with both Prais-Winston regression with panel corrected standard errors (Beck & Katz, 1995) and generalized least squares random effects analysis with an AR[1] correction. Findings for these additional analyses do not vary substantively from the results of the reported OLS FE analyses with an AR[1] correction and are available from the author on request.

3. Elsewhere, through the use of appropriate diagnostics in OLS analyses (e.g., Cook’s Distance), I determine that the two samples analyzed in the current study do not contain any overly influential cases.

4. Primary sector activities are also known to contribute to water pollution (e.g., Coye, 1986), but the estimates analyzed here deal explicitly with organic water pollutants resulting from secondary sector activities (World Resources Institute, 2005), which allows for a more nuanced testing of the second hypothesis.

5. In additional unreported analyses, I include a measure of percentage of total exports in manufactured goods (World Resources Institute, 2005). The effect of manufacturing exports on both outcomes is nonsignificant, and including this additional factor does not alter the findings reported in Tables 4 and 5.

6. Adequate panel data for export commodity concentration were unavailable at the time of this study.

7. Elsewhere, in additional FE panel regression models, I include different measures of state strength and level of democratization (Vanhanen, 1997; World Bank, 2005; World Resources Institute, 2005). The effects of these additional controls on both outcomes are nonsignificant, and their inclusion does not suppress the reported effects of secondary sector foreign investment.

8. In unreported OLS analyses, I investigate variance inflation factors (VIFs) to check for possible model instability because of multicollinearity. All VIFs are well within acceptable levels, with most falling below a value of 2.0 and the highest falling below a value of 3.0.

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