Deforestation and the Environmental Kuznets Curve: A Cross-National Investigation of Intervening Mechanisms*

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Objective. We draw on ecological modernization theory and international political economy arguments to examine the sources of an environmental Kuznets curve (or EKC) that produces an inverted U-shaped rate of deforestation relative to economic development. *Method*. We use ordinary least squares regression with White's (1978) correction for possible heteroskedasticity to examine the rate of deforestation (1980–1995) in less developed countries. *Results*. Net of controls for initial forest stock and the quality of deforestation estimates, we find strong evidence for an EKC driven by (1) agglomeration effects linked to the level of urbanization, (2) rural-to-urban migration that partially offsets rural population pressure, (3) the growth of services-dominated urban economies, and (4) strong democratic states. We find little evidence that foreign debt or export dependence influence the deforestation rate. *Conclusions*. Although deforestation continues to pose pressing and potentially irreversible environmental risks, there is evidence of self-corrective ecological and modernization processes inherent in development that act to mitigate these risks.

Deforestation is a pressing environmental problem involving permanent loss of species, soil degradation, impact on global climate change, and long-term resource depletion. Of the approximately 3.4 billion hectares of forest land that existed around the globe in 1980, approximately 5 percent had been cleared by 1995 (FAO, 1997). Although some decline in the rate of deforestation has been detected in the 1990s (with rapid deforestation in some regions being offset by uneven decreases in Brazil and reforestation in some developed nations), there is no guarantee of abatement in the near future (World Resources Institute, 2000). Given the inextricable links between forest cover and biodiversity, soil quality, and atmospheric replenish-

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ment, understanding the causes and consequences of deforestation must be central to both natural and social environmental science.

Of the various forms of environmental degradation, deforestation holds a special appeal because (1) the felling of trees is spatially fixed and therefore more amenable to study, (2) deforestation is unambiguously due to human activities, and (3) the loss of forest cover is uniquely intertwined with nearly all other forms of environmental degradation. This article extends and improves on prior cross-national analyses of deforestation. Whereas most past studies have been empirical and descriptive, more recent investigations have been more theoretical, emphasizing modernization processes, demographic pressures, and dependency/world systems constraints (e.g., Rock, 1996; Rudel and Roper, 1997; Ehrhardt-Martinez, 1998, 1999). As a part of this theorizing, the existence and implications of an environmental Kuznets curve (EKC) have garnered increasing attention. Given that the actual meaning of this curvilinear relationship between development and deforestation depends heavily on the intervening mechanisms linking the two, the purpose of this investigation is first to establish the existence of an EKC for deforestation and then to examine various competing explanations for this pattern.

The Environmental Kuznets Curve

Speculation about an EKC dates back to the late 1980s, when several researchers noted an inverted U-shaped relationship between various forms of environmental pollution and the level of development (Bernstam, 1990; Beckerman, 1992; Panayotou, 1993; Cole, Rayner, and Bates, 1999). Following Kuznets' (1955) notion that income inequality worsens from low to intermediate levels of development but attenuates as development advances, this environmental analog suggests that ecological damage worsens during early development as nations draw heavily upon their natural endowments to secure industrial "takeoff" and subsequently peaks at intermediate levels of development. Thereafter, as exploitation of the natural environment becomes less central to the economy, environmental damage subsides to some extent. Although this pattern has been found most often for atmospheric contaminants (Grossman and Krueger, 1995; Selden and Song, 1994; Roberts and Grimes, 1997; Torras and Boyce, 1998), an inverted U-shaped relationship between gross national or domestic product per capita and deforestation has been established by a few studies (Cropper and Griffiths, 1994; Rock, 1996; Rudel, 1998; Mather, Needle, and Fairbairn, 1999), and one study establishes the same relationship using urbanization as the development indicator (Ehrhardt-Martinez, 1998, 1999).

Such findings are part and parcel of a larger debate over what has become known as "ecological modernization theory" (EMT), which is the theoretical counterpoint to more radical theories questioning industrial capitalism's ultimate compatibility with natural ecosystems (Buttel, 2000). In essence, EMT argues that capitalist economies have the ability to reform and/or reinvent themselves to promote environmental goals, although the exact processes are matters of debate. Some researchers focus on social structural changes, while others emphasize state intervention and regulation (Murphy, 2000).

The logic underlying EMT and its links to an EKC are controversial. The ultimate question is whether an EKC implies that nations can grow their way out of ecological catastrophes. That is, should we consider environmental degradation a "natural" but ultimately *self-correcting* problem of modern development (a "growing pain" of market industrialism, as suggested by modernization theory), or is such damage actually a permanent feature of industrial capitalist development that intensifies with further development? If so, what accounts for apparent amelioration at higher levels of affluence? The theories used in recent investigations of deforestation offer very different explanations, thus providing a critical experiment as to the possible links between development and forest loss.

Structural Modernization: Technology, Population, and the Economic Base

The core of EMT is the proposition that, although long-term structural change in technology, population, and the division of labor may create short-term disequilibria (e.g. dualism or disarticulation), the continued diffusion of modern technologies and social psychology are ultimately triumphant, supplanting the older social, economic, and political matrices of societies experiencing modernization (Kerr, 1960). Thus, the social problems created by structural modernization are temporary by-products of rapid social transformation and are gradually alleviated by adaptive upgrading processes (Murphy, 2000). Although social problems may grow from low to intermediate levels of development, such problems should subside as modern/industrial institutional matrices gradually replace older, preindustrial social arrangements (Crenshaw and Jenkins, 1996).

Given this logic, EMT views rapid deforestation as a by-product of temporary mismatches between technological regimes, population parameters/dynamics, and the social organization of economic activities. Specifically, under this perspective deforestation is an outgrowth of "traditional" agrarian techniques (e.g., swidden agriculture) and overly rapid population growth early in industrial transformation, whereas declining deforestation and even net reforestation result from changes in land productivity due to the commercialization and mechanization of agriculture, the shift from a rural to an urban-based population, and the evolution of the economic base from extraction/primary production to economic activities far removed from the exploitation of nature (i.e., service sector dominance).

The detrimental impact of farming on forest stock depends upon the interaction between agricultural technology and the population-driven demand for subsistence (Allen and Barnes, 1985; Cropper and Griffiths, 1994; Rudel and Roper, 1997). At constant levels of technology, the rapid population increase characteristic of the first stages of the demographic transition will accelerate deforestation in a process Rudel and Roper (1997:56) describe as the "immiserization model." Paralleling classic Malthusian arguments, population increase in rural areas leads to forest clearing. This rapid deforestation, however, is limited to the early to intermediate stages of development. As development proceeds, the introduction of superior agricultural technologies coincides with decreasing population pressures, resulting in slower deforestation and, ultimately, in reforestation (Rudel, 1989; Allen and Barnes, 1985; Ehrhardt-Martinez, 1998, 1999; Tole, 1998).

Following the same logic, any process that removes excess population from rural areas is likely to reduce forest loss. All else constant, rapid rural-to-urban migration should relieve some pressure on woodlands. Moreover, the age selectivity of urban migrants should have a unique impact over and above the simple siphoning off of population from rural areas. Given that it is young adults who generally migrate to cities, rural-to-urban migration disproportionately removes the age segment most responsible for new family formation and therefore land clearing from the rural milieu (Kasarda and Crenshaw, 1991; Ehrhardt-Martinez, 1998, 1999). EMT would therefore expect a negative interaction between rural population pressure and rural-to-urban migration in that the impact of population growth should be partially mitigated by the degree of migration-induced urbanization.

Finally, EMT would expect urbanization to have a unique influence net of demographic dynamics. As Ehrhardt-Martinez (1998:571) notes, an inverted U-shaped relationship between the level of urbanization and deforestation rates might be expected because of changing energy use, industrial composition, and ecological agglomeration. Early urbanization processes are greatly dependent on resource extraction, and timber for construction and firewood/charcoal for household and industrial use are in high demand during nascent urbanization. Advanced urbanization, however, is characterized by largely complete urban infrastructure, a shift to new building materials, and increased use of petroleum, coal, and electricity, all of which reduce the extraction pressures on forested areas. These processes may create new negative environmental externalities (e.g., air pollution, greenhouse gas–driven climate change) but should slow the rate of deforestation.

Economic evolution toward a nonextractive service and industrial economy should also slow deforestation. As a society's economic base grows more productive, more labor and sustenance/capital (i.e., social surplus) become available to support complex social organization (Lenski, 1966). Through specialization, populations acquire subsistence through complex social networks. Distributive mechanisms grow more complex, leaving an expanding population to rely more heavily on the social structure rather than on the physical environment. As the ratio of information to material production increases and the service sector grows (Spencer, 1898; Turner, 1993:29), cities and agglomeration economies become prominent. Urban agglomeration makes economies more efficient, thus reducing the rate of natural resource use relative to economic product. These changes also reduce the labor force in extractive industries and direct investment from rural hinterlands toward urban enterprise. This strand of EMT therefore argues for an interaction between service sector dominance and urbanization.

The New Politics of Pollution: Democracy and State Strength

Another strand of EMT asserts that development encourages environmental responsibility through changes in mass values, consumption, and demand for government activism on behalf of the ecosystem. Thus, advanced market economics reduce environmental damage through attendant political changes rather than social structural changes per se (Torras and Boyce, 1998). Murphy (2000:3) refers to "the new politics of pollution" to capture this environmental improvement as educated populations, through a combination of environmentally friendly consumption and political lobbying, directly influence the system of production and, more indirectly, pressure government to attend to environmental protection via laws and regulations.

The impact of popular commitment to environmentalism is contingent, however, on the responsiveness of the state to public pressures. Several researchers argue that democratization makes the state more active in protecting the environment (Midlarsky, 1998; Didia, 1997). First, by providing greater freedom of speech and action, democracies have greater environmental activism and, because of electoral competition, are more responsive to such activism and proenvironmental public opinion. Second, democracies typically separate the political from the economic sphere, providing a possible governmental check on environmentally degrading economic activities, such as pollution by state-owned enterprises in socialist economies (Bernstam, 1990). Third, greater press freedom leads to a wider diffusion of information about environmental matters, thereby checking political and industrial corruption.

Empirical tests of the relationship between democracy and deforestation have been inconclusive. Although both Didia (1997) and Mather and Needle (1999) find the expected relationship, their models are not multivariate and likely suffer from severe misspecification. In contrast, Midlarsky's (1998) model is multivariate and examines a sizeable sample, but his findings are counter to this argument: political democracy appears to accelerate rather than retard deforestation. Although Midlarsky controls for important variables such as population growth and gross domestic product (GDP) per capita, he does not incorporate the second-degree polynomial for development (i.e., test for an EKC).

Further, it is important to distinguish between policy responsiveness and policy capacities. As Kitschelt (1986) argues, these may be distinct. Federated states (e.g., the United States) may be more responsive to environmental activism but incapable of policy implementation, whereas centralized states (e.g., France) may be unresponsive but highly capable. Thus environmental protection will be greatest where *both* responsiveness and policy capacity are high. Drawing on Evans' (1995) idea of "embedded autonomy," we argue that environmental protection should be greater among strong proactive states that form partnerships with important elements of civil society. Strong states have the ability to mobilize economic resources, engage in strategic planning, and monitor and control private-sector activities (Rueschemeyer and Evans, 1985), but they may use these greater powers to the detriment of the ecosystem, as the environmental track record of several socialist states indicates (Bernstam, 1990). On the other hand, weak states may be more responsive to social interests but less able to institute coherent environmental programs (Crenshaw and Jenkins, 1996). Thus, "muscled democracy" that combines democracy with strong policy capacities should have the greatest impact.

International Political Economy: Debt, Trade, and Global Stratification

International political economy theory (IPE) provides an alternative framework to ecological modernization theory, arguing that ecological damage is a by-product of economic and political relationships between the developed core and the underdeveloped periphery and semiperiphery (Roberts and Grimes, 1997). Under this perspective, the natural resources of peripheral and semiperipheral countries are basic factors of production for global capitalism, which allows environmental protection to develop in the core while accelerating environmental destruction elsewhere. Accordingly, apparent EKCs in core countries do not suggest the ultimate compatibility of industrial capitalism with the natural world but rather the ability of core countries to shift the environmental burdens of their overconsumption onto the periphery and semiperiphery. Thus, underdeveloped countries will not experience the virtuous environmental cycle promised by the EKC (Ekins, 1997; Rothman, 1998).

Research on deforestation using this perspective has focused on the debt crisis, wood and primary products exporting, and global stratification in general. Foreign debt is argued to lead governments to promote wood and other agricultural exports that result in timber harvesting as well as other land use changes. Cross-national studies have found that deforestation in less developed countries (LDCs) is linked to greater foreign debt burdens (Inman, 1992). Kahn and MacDonald (1994) show that structural adjustment policies have prodded LDCs to engage in short-term promotion of agricultural exports (e.g., export subsidies, tax incentives for cattle ranching, land tenure contingent on market production), thus accelerating deforestation.

Dependence on forest exports is also argued to be central, although the evidence is mixed. Tropical wood exports rose over 14-fold between 1950 and 1980, often creating "boom-and-bust" export economies in which old-growth tropical forests were exploited like minerals, discouraging sustainable forest management and creating irreversible soil degradation. Although evidence has been found both for and against a link between primary-forest exports and deforestation (e.g., Allen and Barnes, 1985; Kick et al., 1996; Rudel, 1989), this linkage is critical to the "consumption-based" approach. If deforestation rates attenuate with development and ultimately lead to net reforestation, then the only two plausible causes are *internal* (production-based improvements in resource usage, as in EMT) or *external* (consumption-based shifts in production externalities, as in IPE).

The impact of global stratification on deforestation is generally formulated using world systems theory. According to this theory, a country's position within the global capitalist system determines its internal dynamics and attendant social problems (Wallerstein, 1974). Core countries are at the center of the global system, wielding economic and political power over semiperipheral and peripheral nations. Problems in the periphery are more reflective of the interests of the core than of internal demands, as exemplified in arguments of export dependence. In contrast, semiperipheral countries are rapidly industrializing with foreign investments and strong authoritarian states that experience major environmental problems. Thus, any EKC is an artifact of this global stratification system. Pollution and environmental degradation are least severe in the periphery and core but greatest in semiperipheral countries, where problems created by strong states, foreign investment, debt, and rapid industrial growth are compounded (Burns et al., 1994; Roberts and Grimes, 1997).

Methodology and Data

Although several studies (e.g., Inman, 1992; Allen and Barnes, 1985) have examined changes in forest *stock,* this does not tap the *pace* or perhaps the *process* of deforestation, which is crucial to any test of an EKC. Our dependent variable is therefore the average annual *rate* of deforestation. To ensure temporal ordering, independent variables are lagged (see operational definitions below). Our sample consists of all LDCs with available forest cover estimates that experienced net deforestation between 1980 and 1995 (see Table 1 for the regional distribution of the sample). We use the Food and Agriculture Organisation (FAO) estimates of total forests coverage for 1980–1995 (FAO, 1999), which provides a better measure of deforestation

TABLE 1

Descriptive Statistics for Regression Variables

Variable	Mean	*SD*	*N*	Source
Deforestation rate 1980–95	.978	.77	74	WRI (1999)
Log forest stock 1980	8.43	2.30	74	WRI (1999)
Data reliability	.216	.42	74	FAO (1995)
Log GDP/c 1980	7.34	.89	56	World Bank*(1999)
% urban 1980	37.6	22.22	74	World Bank (1999)
Population pressure	.667	.55	64	World Bank*(1999)
R/U migration 1970–1990	7.43	9.13	70	World Bank* (1999)
Labor in services 1980	27.82	15.69	64	World Bank* (1999)
Secondary education 1980	32.18	21.35	74	World Bank (1999)
Protected areas 1991	6.49	7.11	64	WRI (1999)
Government scope 1980	6.27	1.75	59	Gurr, Polity II (1990)
Democracy 1980	2.57	3.27	65	Gurr, Polity II (1990)
Debt level/GDP 1980	.34	.25	54	World Bank* (1999)
Change in debt 1980–1990	21.86	15.29	64	World Bank* (1999)
Forest exports/GDP 1980	.0014	0.003	53	WRI/FAO* (1999)
Forest export/Global forest exports	.014	0.046	61	WRI/FAO* (1999)
Forest import/Global forest imports	.013	0.022	71	WRI/FAO* (1999)
Imports/Exports 1980	5.715	10.862	60	WRI/FAO* (1999)
Semiperiphery	.271	0.450	54	Snyder and Kick (1979)
Africa/Asia/Latin America			30/23/21	

*Indicates the variable was computed.

than the loose forest and woodland measure. Total forest cover measures for developed countries are not available prior to 1990, and we need at least a decade to identify significant change. Although excluding developed countries will produce more conservative statistical estimates for some variables, particularly those associated with the EKC and EMT (given that we are eliminating the highest ranges of modernization variables such as GDP per capita), we see this as an advantage. If an EKC can be established in a sample consisting only of LDCs with net forest loss, it would provide compelling evidence that EKCs are not simply artifacts of a global stratification system.

Operationalizations

The dependent variable, the rate of deforestation 1980–1995, is the average annual percentage loss in forest area based on the FAO's measures of total forest coverage area for 1980 and 1995 (FAO, 1999). The means, standard deviations, sample coverage, and sources for each variable are reported in Table 1.

We control throughout for forest stock and the quality of forest estimates. Forest stock (logged to correct for skewness) is the number of hectares of total forest area for 1980 (FAO, 1995) and controls for the possibility that either abundance or scarcity influences the rate of deforestation. The rate of deforestation may be lower in countries with greater expanses of forested land simply as a function of the large denominator in the calculation of the rate. On the other hand, LDCs with scarcity may experience high production costs and political actions to preserve woodlands, thereby promoting lower rates of deforestation (Rudel, 1998). We also use a dummy control for the reliability of the forest measures (0 = low; 1 = high), identifying those LDCs in which either the 1980 or 1995 forest cover measure was based on estimation rather than field observation and should therefore be of lower quality.

The analysis proceeds in three steps: structural modernization models, political modernization models, and IPE models. To preserve sample sizes, we incorporate a reduced form of our EMT model into the latter two sets of models. The first set includes real GDP per capita, urbanization, population growth, rural-urban migration, and service sector employment. Real GDP per capita is measured for 1980 and is logged to correct for skewness; urbanization is the percentage of the population living in urban areas in 1980 (World Bank, 1999). To test for a curvilinear effect of GDP per capita and urbanization, we used quadratic terms as predicated by an EKC.

Rural population pressure is based on the geometric mean of the annual average percentage change in the rural population between 1970 and 1990 and rural population density in 1980. Rural population growth is thus weighted by the population density of rural districts, thereby tapping their degree of demographic saturation. Rural-urban migration is estimated by subtracting the rural population growth rate from urban population growth rate for the period 1970 to 1990. As fertility rates are nearly always higher in rural areas (Kasarda and Crenshaw, 1991), a positive measure of urban population growth—above and beyond the rate for rural areas—can be largely attributed to internal rural-to-urban migration. The size of the service sector in 1980 is measured as the percentage of the labor force working in service sector jobs (World Bank, 1999).

To capture political modernization, we use education, governmentally protected natural areas, the scope of government actions, and the level of democracy. Education is measured as the percentage of the population that had attended school at the secondary level (generally seventh year or above) in 1980 (World Bank, 1999). It should tap awareness of environmental risks as well as political pressures on states to protect the environment. We measure government protection by the percentage of total land area under protected status in 1991 (World Resource Institute, 1998), the earliest available year with sufficient coverage for statistical analysis.

To capture the ability of states to regulate their social systems, we use the scope of governmental actions in 1980 (adapted from *Polity II;* Gurr, 1990). The scale is a continuum that measures the extent to which all levels of a government attempt to regulate and organize the economic and social life of its citizenry. We reverse-code it such that the most regulatory states receive the highest score, whereas the least regulatory states receive the lowest (scored one to nine).

The democracy variable measures the degree to which democracy has been institutionalized within a country as of 1980 (Gurr, 1990). This is an additive 10-point scale that taps three independent elements of democracy: (1) the presence of institutions and procedures that can be used by citizens to express their preferences about leaders and policies, (2) the existence of institutionalized constraints on the exercise of executive power, and (3) the guarantee of civil liberties for all citizens in both political participation and everyday life. High scores indicate high levels of democracy. The combination of strong state capacities and democracy is tapped by the multiplicative interaction of governmental scope with political democracy.

To capture IPE, we use international debt, trade in forest exports, and world systems position. Debt is measured as both the level of debt in 1980 and the change in debt between 1980 and 1990 (World Bank, 1999). The level of total public guaranteed long-term external debt (current $US measured in 1980) is standardized by dividing it by GDP at factor cost (current $US, 1980). Debt change is the average annual percentage change in this debt level between 1980 and 1990. We measure export trade in forest products in four ways: (1) the value of forest exports as a proportion of real GDP (factor cost) in 1980, (2) the value of forest exports as a proportion of the total global value of world forest exports in 1980 (proxied by aggregating the forest export values for our sample countries), (3) the value of forest imports as a proportion of the total value of global (i.e., sample) forest imports for 1980, and (4) the ratio of the value of forest imports to forest exports for 1980. All data come from the World Resources Institute (1998, 2000). The first gauges the importance of forest exports to a nation's economy, whereas the second and third effectively create rankings of exporting/importing activity among the countries in our sample. The final variable captures the extent to which domestic consumption exceeds exports, a direct test of IPE's pseudo-EKC notion. Ratios above one indicate that consumption exceeds domestic export production of forestry products, whereas ratios below one indicate the opposite. If IPE is correct, this ratio should be negatively related to deforestation and, if core nations are substituting LDC forests for their own, it should cancel the direct effect of the EKC. Finally, world systems position, adapted from Snyder and Kick (1979) as modifed by Bollen (1983), indicates a country's stratum within the global system. Because we focus on LDCs, we use a dummy variable with semiperipheral status coded 1, which should be associated with a higher rate of deforestation and thereby wash out any pseudo-EKC effect.

We tested all equations for multicollinearity using variance inflation factors and tolerance statistics. Although critical values for terms in our second-degree polynomials and multiplicative terms did suggest collinearity (which is to be expected), repeated sampling and specifications suggest no strong sensitivity in the reported inferential statistics. Outlier analysis

TABLE 2

Rate of Deforestation Regressed on Structural Modernization Variables, with Standard Errors (in Parentheses) Corrected Using White's (1978) Procedure

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	−7.498**	−2.950	.806	.745	.186	.440
	(3.181)	(3.968)	(.661)	(.803)	(.689)	(.652)
Forest stock 1980	−.107*	−.120**	−.095*	−.094*	−.064	−.087*
	(.056)	(.048)	(.054)	(.055)	(.050)	(.051)
Data reliability	−.456***	−.433**	−.415**	−.410**	−.406**	−.404**
	(.179)	(.187)	(.168)	(.174)	(.159)	(.155)
Log GDP/c 1980	2.764***	1.362				
	(.902)	(1.079)				
Log GDP/c squared	−.196***	−.097				
	(.059)	(.666)				
% urban 1980		.030	.058***	.059***	.054***	.026***
		(.020)	(.014)	(.019)	(.017)	(.009)
Urban squared		−.0004**	−.0008***	−.0009***	−.0008***	
		(.0002)	(.0002)	(.0002)	(.0002)	
Population pressure			.528**	.536*	1.283***	1.237***
			(.257)	(.271)	(.376)	(.371)
R/U migration 1970–1990				.0019	.043**	.040**
				(.007)	(.016)	(.018)
Population * Migration					−.092**	−.094**
					(.036)	(.037)
Labor in services 1980						.037***
						(.014)
Services * Urban						−.001***
						(.0003)
N	63	63	64	64	64	64
R^2	.23	.31	.43	.43	.50	.50
R^2 adjusted	.18	.24	.38	.37	.44	.43

***$p < .01$, two-tailed test. **$p < .05$, two-tailed test. *$p < .05$, one-tailed test

suggested that Jamaica, Bahamas, and Cote d'Ivoire were influential cases. Jamaica had the highest deforestation rate in the sample (and, indeed, the world) at 4.41 percent per annum, due to swidden agriculture, timber "poaching," and specific land-degrading commerical crops such as coffee. Cote d'Ivoire's rate of 3.66 was also excessive, probably because of coffee production and confused land tenure laws, leading to wasteful agrarian practices. The Bahamas has the developing world's most dominant service sector (76.8 percent), which made it an outlier in the service sector equation. Dropping these three cases increased the adjusted R^2 but did not alter the signs of the coefficients, indicating that these are not influential cases. Thus we include them in the models shown. Adding controls throughout for world region did not change the substantive findings. Because of mixed evidence of heterosketasticity, we applied White's (1978) correction for standard errors to our reported results.

Results

Table 2 reports the tests of structural modernization theory. Model 1 establishes the importance of controlling for initial forest stock and data reliability. As we anticipated, the larger the initial forest stock, the slower the rate of deforestation. Moreover, the average deforestation rate for countries whose forest stock indicators are based on direct field observation is significantly lower than the average rate in the remainder of the sample, indicating possible limits of indirect estimation. The EKC is in clear evidence. The log of GDP per capita is positively associated with deforestation until it reaches a threshold of approximately 7.05 (i.e., approximately $1,150 per capita, a fairly low threshold), after which this association gradually becomes negative (i.e., the relationship would not, based on these parameter estimates, actually predict net reforestation, but rather a fall in the rate of deforestation). Model 2 suggests that the operative modernization variable is urbanization rather than GDP. Although fairly severe multicollinearity weakens the inferential statistics for both the development and urban polynomials, the second-degree polynomial for urbanization is more robust, its quadratic having attained statistical significance even in the presence of multicollinearity. We therefore conclude that urbanization is the more central dynamic producing the EKC.

Model 3 tests urbanization and rural population pressure. Both are significant and exhibit the expected signs. The polynomial for urbanization suggests that it is associated with higher deforestation until urbanization reaches a threshold of approximately 36 percent, after which urban level apparently leads to a reversal of deforestation rates (i.e., reducing the rate, not to be confused with actual reforestation). Next we control for rural population pressure, which has a strong positive effect on deforestation rates. Models 4 and 5 test the hypothesis that, all else constant, rural-to-urban migration lessens the impact of rural population growth on forest stock. Whereas Model 4 demonstrates no unique influence of rural-to-urban migration, Model 5 reveals a significant negative interaction effect between rural population pressure and migration. At the mean of our estimate of rural-to-urban migration ($X = 7.43$), such migration cuts the magnitude of rural population pressure on deforestation rates an average of approximately 50 percent. Rural-to-urban migration therefore appears to be an important safety valve in relieving demographic pressures on forest stock.

Model 6 concludes our test of EMT by testing for an interaction between services-oriented development and urbanization. Because of multicollinearity between urbanization and percentage labor force in services, we drop the urban quadratic in this equation. In addition to other effects established earlier, our model produces a significant multiplicative term between urbanization and the service sector. Urbanization is positively associated with deforestation only in countries where services fall below 26 percent of the

TABLE 3

Rate of Deforestation Regressed on Structural and Political Modernization Variables, with Standard Errors (in Parentheses) Corrected Using White's (1978) Procedure

	Model 7	Model 8	Model 9	Model 10	Model 11
Intercept	1.645***	1.706***	3.06***	2.489***	2.72***
	(.416)	(.402)	(.338)	(.423)	(.347)
Forest stock 1980	–.099**	–.101**	–.150***	–.176***	–.171***
	(.047)	(.043)	(.040)	(.050)	(.041)
Data reliability	–.354*	–.532***	–.746***	–.768***	–.672***
	(.192)	(.141)	(.135)	(.159)	(.148)0
% urban 1980	.031**	.026**	.030**	.029**	.033***
	(.013)	(.011)	(.012)	(.013)	(.011)
Urban squared	–.0004***	–.0004***	–.0005***	–.0006***	–.0006***
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Secondary education 1980	–.003				
	(.006)				
Protected areas 1991		.008			
		(.009)			
Government scope 1980			–.123***		–.062
			(.048)		(.058)
Democracy 1980				.028	.295**
				(.028)	(.111)
Scope * Democracy					–.043**
					(.018)
N	74	72	55	55	55
R^2	.22	.28	.48	.41	.54
R^2 adjusted	.16	.23	.43	.35	.47

***$p < .01$, two-tailed test. **$p < .05$, two-tailed test. *$p < .05$, one-tailed test.

labor force. Where services constitute a larger share, urbanization retards deforestation. Although multicollinearity prevents us from determining if the urban/services interaction actually accounts for the EKC, our overall findings indicate that there is a structurally based EKC.

Table 3 reports our investigation of the political side of EMT. We include the urban polynomial in all subsequent tests to determine if political variables can explain away this structural modernization effect. Whereas Models 7 and 8 fail to find support for benefits of education or governmentally protected areas, Model 9 reveals a strong benefit of governmental scope. The more invasive and regulatory the state, the lower the rate of deforestation. Political democracy (Model 10) is positive, consistent with Midlarsky's (1998) finding that democracy boosts deforestation but is not statistically significant. Confirming the argument about "muscled democracies," the interaction of state scope and political democracy reduces the deforestation rate (Model 11). Once this is controlled, democracy becomes positive and significant, indicating that weak democratic states (in this sample, scope values below 6.8) may be associated with higher rates of deforestation. This

TABLE 4

Rate of Deforestation Regressed on Structural and Dependency/World Systems Variables, with Standard Errors (in Parentheses) Corrected Using While's (1978) Procedure

	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
Intercept	2.181***	1.931***	2.419***	2.359***	1.932***	2.435***	1.371**
	(.550)	(.578)	(.356)	(.396)	(.448)	(.382)	(.576)
Forest stock 1980	–.155***	–.150***	–.182***	–.166***	–.116**	–.166***	–.076
	(.054)	(.052)	(.042)	(.045)	(.047)	(.043)	(.051)
Data reliability	–.578***	–.535**	–.712***	–.706***	–.617***	–.751***	–.732***
	(.210)	(.203)	(.202)	(.184)	(.168)	(.189)	(.196)
% urban 1980	.046***	.050***	.037***	.029**	.028**	.028**	.053***
	(.017)	(.018)	(.012)	(.011)	(.012)	(.012)	(.019)
Urban squared	–.0007***	–.0008***	–.0006***	–.0005***	–.0006***	–.0005***	–.0009***
	(.0002)	(.0002)	(.0001)	(.0001)	(.0002)	(.0001)	(.0002)
Debt level/GDP 1980	–.556						
	(.376)						
Change in debt 1980–1990		–.001					
		(.004)					
Forest exports/GDP 1980			–28.945				
			(45.462)				
Forest export/Global forest exports 1980[a]				2.26*			
				(1.36)			
Forest import/Global forest imports 1980[b]					5.74		
					(4.20)		
Imports/Exports 1980						.0035	
						(.0060)	
Semiperiphery							.065
							(.216)
N	51	60	51	58	67	56	46
R^2	.36	.31	.39	.35	.32	.37	.36
R^2 adjusted	.29	.24	.33	.29	.25	.31	.28

***p < .01, two-tailed test. **p < .05, two-tailed test. *p < .05, one-tailed test.

[a]"Global" forest exports aggregated from sample.

[b]"Global" forest imports aggregated from sample.

suggests that weak democracies respond to public pressures by allowing forest exploitation. The urban polynomial remains significant throughout this series, indicating the stability of the structural EKC.

Table 4 considers IPE. Overall, the results suggest that dependency and world systems theory have little net impact on deforestation once EMT is appropriately specified. Models 12 and 13 show that neither debt in 1980 nor the rate of debt growth influences deforestation rates. Indeed, these coefficients never attain statistical significance and do not display the correct sign (which should be positive). Additionally, the importance of forest exports to an economy (Model 14) is nonsignificant and negative. We do find a weak but significant effect of global forest export ranking on deforestation (Model 15), suggesting that the higher a nation ranks among exporters of forest products, the more rapid its rate of deforestation. This is, however, the weakest test of IPE theory, in that it might be viewed as simply descriptive of forest exploitation rather than theoretically meaningful.

None of the other dependency/world systems effects reported in Table 4 are significant. Model 16 shows that the curvilinear urbanization effect is not due to the substitution of foreign wood products for indigenous products. Model 17 makes the same point: neither importing nor exporting wood products has any strong influence on deforestation rates. Finally, Model 18 demonstrates that, net of the EKC, semiperipheral position in the world system has no discernable impact on the loss of forest cover.

Conclusions: Sustainable Development?

We have shown that there is an EKC for deforestation rooted in structural and political modernization, especially those dynamics associated with urbanization, the growth of service sector activities, and strong democratic states. Borrowing on EMT, these modernization processes, which include both political and economic changes, slow the rate of deforestation, signifying the need to expand EMT to include both political and economic aspects.

IPE arguments fail to find purchase on deforestation in our analysis. Although LDCs that rank higher in the global wood export trade are experiencing greater deforestation, this may simply be descriptive of their participation in the global wood export market. All else constant, semiperipheral countries do not deforest more rapidly, nor does foreign debt drive deforestation. This undercuts the idea that core countries have transferred their environmental problems to the LDCs, thereby creating a fictive EKC. Thus, paralleling Kuznets' (1955) classic argument that modernization may be detrimental to income inequality and social welfare in the short term but prove beneficial in the long term, we show that there are also offsetting environmental processes at work in modernization.

How beneficial is this EKC? Ultimately, the debate about EKCs centers on whether these self-corrective processes halt deforestation and protect the environment for future generations. Many of the processes associated with deforestation, especially loss of species diversity, soil degradation, and climate change, may be irreversible. Although offsetting processes may slow the rate of deforestation, this does not mean that global development will not eventually result in permanent forest degradation. An important issue for future study is the extent to which the EKC effect actually reverses as opposed to simply slows the rate of deforestation and related environmental degradation.

The idea of an EKC points to the possibility of combining development with policies and forest practices that slow deforestation, perhaps creating environmental sustainability alongside development. There is significant potential for regenerating forests through a combination of governmental investment, land tenure rationalization, increased education, and market reforms (Southgate, 1998). Further work is needed to evaluate the extent to which any EKC effect creates long-term sustainability of forest cover alongside continued economic development.

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