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Institutions and the Environmental Kuznets Curve for Deforestation: A Crosscountry Analysis for Latin America, Africa and Asia

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Summary. — The relationship between deforestation and income across 66 countries of Latin America, Africa and Asia is examined. Institutional characteristics as well as macroeconomic policies of each country are hypothesized to impact deforestation. Results show strong evidence of an environmental Kuznets Curve (EKC) relationship between income and deforestation for all three continents. Institutional structure and macroeconomic policy significantly affect the tropical deforestation process. Improvements in political institutions and governance significantly reduce deforestation. The factors leading to deforestation differ across regions, however, and there is no one-size-fits-all global policy recommendation for restraining the tropical deforestation process. © 2001 Elsevier Science Ltd. All rights reserved.

Key words — deforestation, environmental Kuznets curve, institutions, Africa, Asia, Latin America

1. INTRODUCTION

The major objective of this study is to conduct an empirical analysis of the environmental Kuznets Curve (EKC) for tropical deforestation. The EKC concept is a recent development in environmental economics, particularly since Grossman and Krueger's (1991) path-breaking study of the environmental impacts of the North American Free Trade Agreement. The EKC hypothesizes the existence of an inverted U-shaped relationship between indicators of environmental degradation and economic growth. Unlike other EKC studies, where the relationship between income and specific environmental pollutant levels is analyzed, this study uses tropical deforestation as the indicator of environmental quality and quantifies its relationship with income while controlling for impacts of political institutions, macroeconomic policy, and demographic factors.

Forests embody important environmental attributes and deforestation is viewed as a major environmental problem due to its impact on carbon sequestration and reduction of greenhouse gas emissions, and the enormous amount of biodiversity resources found in tropical forest ecosystems (Brown & Pearce, 1994). Climate change and biodiversity conservation issues are among the major global policy debates of this decade. Nevertheless, the annual conversion of tropical forest to other land use was about nine million hectares during 1980–90 (FAO, 1997). In this context, cross-national empirical studies on tropical deforestation covering wide geographical areas provide valuable empirical inputs to policy recommendations with respect to global environmental issues.

Several factors affecting the present level of tropical deforestation are identified in the literature. Among these are population growth and population density (Allan & Barnes, 1985; Burgess, 1992; Rudel, 1994; Rudel & Roper,

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1997), shifting cultivation and slash and burn farming practices (Myers, 1994), timber harvesting and commercial logging (Capistrano, 1994), national debt (Kahn & McDonald, 1994), increased fuelwood demand, burning and grazing, construction of penetration roads, and weak forest protection institutions (Repetto & Gillis, 1988; Brown & Pearce, 1994), and insecure tenure and property rights and ownership risk (Southgate, 1998; Deacon, 1999).

Though population growth and shifting cultivation, and commercial logging and timber harvesting are frequently cited as leading factors for excessive deforestation, the relationship between these factors and deforestation is filtered though and shaped by institutions and policy conditions facing society. Thus, the impact of institutions on deforestation deserves special scrutiny. Heretofore, the empirical basis for linking deforestation to an underling broad sociopolitical institutional framework is scanty (Deacon, 1995). Some of the country-specific deforestation case studies have identified other factors as primary causes, including prices of round wood, inappropriate road building and infrastructure development, weak institutions to enforce rules and regulations, and tenure insecurity (Barbier, 1997; Burgess, 1992; Southgate & Runge, 1990; Southgate, Sierra, & Brown, 1991). But, we cannot draw reliable regional or global inferences based on case studies findings conducted in one or two countries. Therefore, a crossnational study is applied here to test the regional integrity of the EKC hypothesis, and to assess any implications that can be drawn from such EKC studies affecting regional and global environmental programs.

Before Grossman and Krueger's (1991) empirical study of the EKC, and Shafik and Bandhyopadhyay's (1992) study of the EKC for deforestation, Samuelson hypothesized the notion of an EKC relationship with respect to forestry and conservation in a seminal paper on the economics of deforestation in 1976. [1] He also noted the importance of public policy and institutions in the forestry sector.

This study is an investigation of the EKC hypothesis where the rate of deforestation—annual percentage change in forest and woodlands area—is used as the measure of environmental degradation. Factors explaining this process of primary interest for this analysis are per capita income and various measures of institutional structures—political and civil liberties—within each country. Other factors such as macroeconomic policy and structural settings, as suggested by previous studies, are also included in the analytical models presented here.

Section 2 of the paper summarizes selected recent literature on environmental quality and income growth and the relationship between deforestation and income. Section 3 presents the variables selected for the study, their likely impacts, and data sources. Section 4 presents the empirical model and estimation techniques. Results are discussed in Section 5. Conclusions are given in Section 6.

2. LITERATURE ON THE EKC [2]

Kuznets (1955) originally proposed an inverted U-shaped relationship between income growth and income inequality, which is known as the Kuznets Curve. More recently, environmental economists have built on this notion by hypothesizing the same type of relationship between income growth and environmental degradation and this has become known as the Environmental Kuznets Curve. The EKC approach links the level of environmental degradation (protection), given by selected environmental indicators, to the level of economic development of a country or region. This approach implies that during the initial stage of development, some form of environmental degradation is inevitable, but increasing income would ultimately produce incentives to improve environmental quality. Therefore, one of the policy implications of the EKC is that development that produces pressures on the environment is sustainable so long as the development continues to the level where environmental restoration begins, and that the development process does not exceed ecological threshold (irreversibility) limits. [3] This does not mean, however, that there is a diminished role for policy and institutions in environmental programs during the early growth stage, rather it implies that the negative impacts of development programs should be restrained within the limits of ecological thresholds by prudent environmental policies.

The other major contribution of EKC studies of global environmental policy is to encourage restructuring of development policy programs to move to a sustainable growth path by flattening the EKC curve for the environmental indicators in question. The aim of this process

is to avoid the same level of environmental harm experienced by industrialized countries during their early growth phases without hindering economic development (Munasinghe, 1999; Panayotou, 1995).

Most empirical EKC studies base their analysis on an objective measure of environmental quality, such as measured observations of sulfur dioxide levels, river pollutants, or suspended particulate matter (Shafik & Bandhyopadhyay, 1992; Seldon & Song, 1994; Panayotou, 1997; Shafik, 1994a; Grossman & Krueger, 1991; Grossman & Krueger, 1995; Yandle & Qin, 1998). Empirical results suggest that EKCs exist but statistical support is not uniform across all indicators of environmental quality. Depending on the type of environmental quality indicator selected, country or group of countries in the study, other explanatory variables used in the model, and the time period selected for the study, results are mixed. In addition, findings are also sensitive to the econometric technique selected for the analysis (Stern, Common, & Barbier, 1996). Besides empirical studies, theoretical exploration of the EKC framework is still at an infant stage, though recently, some authors have attempted to explore these issues (Munasinghe, 1999; Lopez, 1994; Vogel, 1999).

The relationship between institutional changes and increased prosperity is another complex but little analyzed topic within the scope of environmental analysis. The relationship between income growth and environmental quality is not straightforward, but involves a complex feedback mechanism passing through various institutional channels affecting both market and political forces (Antle & Heidebrink, 1995). It is also suggested that improved literacy, and democratic governing institutions and citizen participation in decision-making would weaken the income effect of the EKC hypothesis. Torras and Boyce (1998) reported that institutional factors affect the EKC relationship, particularly in low-income countries, and they suggest that wider literacy and greater political liberties and civil rights could positively affect environmental quality. Likewise, Panayotou (1997) reports that environmental policy could enable a harmonization between economic growth and environmental quality. He suggests that the quality of policies and institutions, such as secure property rights and better enforcement of contracts, can help flatten the EKC and reduce the environmental price of economic growth.

Institutions contribute to the efficiency and growth of economies, and thus, influence the shape of the income-environment relationship. Some of the crosscountry empirical studies of institutions and economic growth have reported that politically open societies which respect the rule of law, private property, and the market allocation of resources grew much faster than societies where these freedoms were restricted (Knack & Keefer, 1995; Scully, 1988).

Some believe that when national income grows to a sufficient level there is a transformation of the structure of the economy. In many countries, forest products are substituted by alternative sources for energy use, which would ultimately lower the deforestation rate thus, giving rise to the EKC relationship (Cropper & Griffiths, 1994). This line of argument is consistent with the environmental transitional hypothesis (Goklany, 1999; Antle & Heidebrink, 1995). It is also possible that society places a greater emphasis on environmental use value of forest resources which are mostly nonmarket in nature, such as biodiversity and wildlife conservation, aesthetic value, and carbon sequestration, only at higher income levels. Such environmental use of forest resources is a luxury, which a society would demand action upon only when its other basic needs are met. How this type of transformation takes place, and whether all societies have to pass through the same transformation process, remains unclear. The limited available empirical literature on the topic of the EKC for deforestation has provided mixed results (Shafik & Bandhyopadhyay, 1992; Cropper & Griffiths, 1994; Shafik, 1994b; Koop & Tole, 1999; Mather, Needle, & Fairbairn, 1999). None of these studies incorporates institutional factors into the EKC analysis.

Most of the crossnational studies on economics of deforestation have focused analysis on population impacts (Allan & Barnes, 1985; Cropper & Griffiths, 1994; Koop & Tole, 1999; Mather *et al*., 1999). The emphasis on population is at least partially due to the lack, until recently, of a consistent set of reliable statistics for other major institutional and macropolicy variables for many countries. Recent attempts by the World Bank growth research teams and other crossnational study centers, such as Freedom House Publications, now provide two decades of consistent and comparable institutional statistics across countries. It is hypothesized in this study that institutional structure plays an important role in the implementation

of environmental policy and the relationship between environmental quality and societal income.

3. DATA AND MODEL SPECIFICATION

This study examines the relationship between the rate of deforestation and income in 66 countries from the tropical regions of Latin America, Africa, and Asia for 1972–91. More specifically, there are 20 countries from Latin America, 31 countries from Africa, and 12 countries from Asia that fit the geographical restriction and for which consistent data are available for the complete time period. [4] The countries selected for the analysis are listed in Table 3 in Appendix A. Developing countries, most of which are tropical, account for 59% of the land area of the world and 57% of world forests (FAO, 1997). The criteria adopted to include a country in this study are that the country should have at least 1,000,000 hectares of forest and woodlands area in 1990, and the country is found in the tropical developing regions of Latin America, Africa and Asia. These criteria eliminate the Middle East oil economies and Northern African countries, as well as many others, but they provide a comparable set of environmental and economic conditions across a wide geographic area.

(a) *Forest area definition*

Consistent and reliable statistics of forest and woodlands, institution factors, and some of the macro statistics for many small developing countries are not available for the period before 1970. This is particularly true for many African countries that have only recently become sovereign countries. Some previous studies of the EKC for deforestation have used forest statistics from 1961 (Shafik & Bandhyopadhyay, 1992; Shafik, 1994a; Cropper & Griffiths, 1994; Koop & Tole, 1999); however, several scholars have also criticized these because of the data problem (Angelsen & Kaimowitz, 1999; Stern *et al*., 1996; Rudel & Roper, 1997; Arrow *et al*., 1995).

There are also some controversies in the literature related to definition of deforestation, and how best to define it across countries over time (Arrow *et al*., 1995; Stern *et al*., 1996). Previous studies on the EKC for deforestation and econometric modeling exercises on deforestation (Shafik, 1994b; Cropper & Griffiths, 1994; Koop & Tole, 1999; Mather *et al*., 1999) have used FAO data on forest and woodlands to measure deforestation without regard to the data problems associated with these statistics. FAO (1993) defines forest and woodlands area as

> ... land under natural or planted stands of tress, whether productive or not, that includes land from which the forests have been cleared but that will be reforested in the foreseeable future. This also includes the forest clear cut land that is still under the jurisdiction of Forest Authority and has not yet been converted to agriculture or other plantation.

There is no reliable source of crosscountry comparable forestland statistics for developing countries except FAO. FAO follows uniform procedures to collect forest area statistics across tropical countries at least since the early 1970s. But, due to the difference in the definition of forests and woodlands between industrialized and developing countries, the FAO statistics on forest and woodlands are not comparable across these two categories of countries.

FAO's annual data on forest and woodlands area are projections based on forest inventories done at 10-year intervals starting after 1970 in most developing countries. FAO verifies the data with field level information gathered from annual surveys of governmental agencies, as well as FAO field offices. Most scientific forest inventories in developing countries were initiated only after the late 1960s or early 1970s, when tropical deforestation first became an international concern. Considering the dubious reliability of forest statistics before the 1970s, this study limits the analysis to 1972 onward. The deforestation rate used in this study is the annual percentage change in forest and woodlands area.

(b) *Explanatory variables*

(i) *Income*

Descriptions of the variables used in the regression analysis, their unit of measurements, and their expected relationship with the deforestation rate are summarized in Table 1. The relationship between deforestation and societal income validates the presence or absence, of an EKC relationship in the forest sector. A cubic form regression model is applied in this study to give a flexible specification of the EKC re-

Table 1. *Variable definitions and their expected relationship with the deforestation rate*[a]

Explanatory variable	Unit	Description	Expected sign
GDP	US$	PPP adjusted GDP per capita 1985 US$1,000s, lagged one period	Positive
GDP squared			Negative
GDP cubed			No prediction
Time		An indicator of other exogenous time dependent variables	No prediction
Political institutions	Index	Sum of political rights and civil liberties indices (2–14)	Negative
Black Mkt FOREX	%	Black market premium on foreign exchange	No prediction
Debt	%	Debt percentage of GDP	Positive
Population growth	%	Annual percentage population growth rate	Positive
Rural POP density		Rural population per 1000 square km	Positive
Change in cereal yield	%	Annual percentage change in cereal yield index	No prediction

[a] *Sources*: (1) Deforestation rate is derived from change in forest and woodlands area taken from FAO (various years). (2) GDP, Black Mkt FOREX, and Debt are obtained from the World Bank Growth Research Datasets, provided on the Bank's web site at http://www.worldbank.org/growth/index.htm. (3) Population growth and Rural POP density are obtained from the World Bank (1998). (4) Change in cereal yield is obtained from the WRI (1998). (5) Political institutions is obtained from the Freedom House datasets available at http://www.freedomhouse.org

lationship. The EKC hypothesis suggests that the coefficient of the income term would be positive, and the coefficient of the quadratic income term would be negative in the regression model. There is no *a priori* expectation, however, on the sign of the coefficient of the cubic income term. The available empirical literature is ambiguous with respect to the sign of the cubic income term (Goklany, 1999). Mather *et al*. (1999) obtained a negative sign for the cubic income term in his deforestation EKC model.

(ii) *Institutions*

This study assumes that growth of income is accompanied by improvement in sociopolitical institutions, environmental rules and regulations, and the allocation of environmental resources, which are generally considered public goods. It is therefore, hypothesized that underlying institutional and policy conditions affect the relationship between deforestation and income, and shift the EKC upward or downward accordingly. The institutional variable used in this analysis is the sum of political rights and civil liberty indices taken from Freedom House data, as described by Scully (1992) and Gastil (1987), and published in the Freedom House yearly publications. [5] These indices are sometimes also called Freedom House indices or Gastil indices of political and civil rights. Some recent studies on the relationship between institutions and environmental policy, and institutions and economic growth and development have used these same indices (Torras & Boyce, 1998; Barro, 1996; Isham, Kaufmann, & Pritchett, 1997).

The political rights index (with values 1–7) of a country for a given year is constructed by Freedom House analysts based on 12 different freedom-related criteria including fair election laws and campaigning opportunities, polling process, election of the chief executive, the role of the opposition party in the political process, and legislators' election processes. The civil liberty index (with values from 1 to 7) is constructed from 25 different individual freedom-related factors such as free press and media, independent judiciary system, rule of law, open public discussion, freedom of assembly and demonstration, individual rights, free business or cooperatives, protection of personal property rights, personal and social rights, other socioeconomic rights, and corruption in government. The index value is one for countries with the most political and individual freedom (United States) and seven for the least freedom (Afghanistan). For ease of interpretation of the regression results and to have a comparable outcome with other variables, these indices are reversed in order so an increase in value implies an increase in freedom and political rights. The political rights and civil liberty indices were summed together to create a new variable—political institutions—used in the deforestation model. The political institutions variable ranges from 2 to 14. This provides larger variation of institutional settings and therefore, better parameter estimates. The cardinal measure of the index allows us to quantify the marginal

impacts of the improvement of institutional factors on the deforestation process. It is expected that an improvement in institutions will lower the deforestation level and shift down the EKC.

(iii) *Macroeconomic policy*

Two macroeconomic policy variables, the black market premium on foreign exchange and external debt as a percentage of GDP, are hypothesized to affect the deforestation process. Other macroeconomic and sectoral policy instruments such as the real interest rate, the real exchange rate, rural unemployment, and tax and subsidy rates on forest products may also be important factors for deforestation decisions. Comparable data for such variables are not readily available, however, for many of the countries included in the analysis. Therefore, the study is restricted to these two macroeconomic policy variables.

The black market premium on foreign exchange is a proxy for the exchange rate as well as trade policies. It reflects the overall macro policy environment, with particular importance for export/import industries including the forestry sector. Repetto and Gillis (1988) cite exchange rate policy as a critical factor affecting deforestation decisions. The black market premium on foreign exchange also measures the overall macro policy environment. For example, a high black market foreign exchange rate indicates a restrictive trade policy and overvaluation of domestic currency. Currency overvaluation negatively affects the private rents of the timber exporting industry. At the same time, however, it discourages local nontimber forest products industries. Thus, the net result of exchange rate and trade policy on tropical deforestation is not clear and there is no *a priori* predicted sign for the coefficient of the black market premium variable in the deforestation model.

Recently, there has been considerable discussion of debt relief, particularly for some of the least-developed countries. Debt payments often consume a large portion of developing countries' annual budgets and foreign currency earnings; thus, squeezing out needed investment in public programs including environmental protection. The political economy of the management of the debt burden process is complicated, and it also reflects the strength of governmental institutions or existing structural constraints. The net impact of debt as well as options available for the country to reduce the debt burden depend upon its creditworthiness, export base, level of exposure, integration with global capital markets, and the development base of the economy. Debt can lead to myopic behavior, causing excessive deforestation in the short run, which is not optimal in the long run but necessary to meet current constraints and past obligations (Kahn & McDonald, 1995). Debt-for-nature swaps provide an opportunity to escape the constraints imposed on a country by a heavy debt burden. This form of debt management is increasingly being practiced as a means to relieve debt and conserve endangered tropical forests. The actual microeconomic determinants of deforestation may differ by country; however, it is hypothesized in this study that a large foreign debt burden aggravates shortsighted policies and leads to deforestation levels above the social optimum.

(iv) *Population factors*

Population growth and rural population density are two population-related variables that have been widely used in previous empirical studies on deforestation. Excessive population growth and population pressure in developing countries are commonly cited as key factors inducing excessive tropical deforestation (Myers, 1994; Cropper & Griffiths, 1994; World Bank, 1992; Palo, 1994; Allan & Barnes, 1985). Templeton and Scherr (1999) argue, however, that population pressure is a two-edged sword. They suggest that population pressure initially may cause increased tropical deforestation, but once population grows to a certain level production processes are changed to improve efficiency, thus conserving remaining natural resources. Considering the controversial role of population pressures on the tropical deforestation process, two separate variables—population growth and rural population density—are used in the deforestation model. This approach highlights the impact of population structure; whether it is rural population pressure or the overall population level that affects the deforestation process. It is hypothesized that an increase in both population growth rate and rural population density will lead to increased deforestation.

(v) *Technological change*

Most time-series studies use a time trend as a proxy for technology change. There are, however, several limitations to this approach. Considering the importance of technology in the EKC analysis, a more realistic representa-

tion of technical change in the rural economy is given by the annual percentage change in cereal crops yield. Percentage change in cereal yield is constructed from FAO statistics on cereal yields for each country. The annual percentage change in cereal yield provides a linkage between technological change in the agricultural sector and the deforestation process. The impact of technological change in agriculture varies, however, depending on whether it is capital saving or labor saving. Angelsen and Kaimowitz (1999), based on their review of more than 140 economics studies on deforestation, found no conclusive empirical evidence that technological progress increases or decreases deforestation; therefore, the sign of the coefficient of percentage change in cereal yield is not predicted *a priori*.

(c) *Data sources*

Forest and woodlands statistics are taken from FAO (various years). GDP per capita, debt as percentage of GDP, the black market premium on foreign exchange, and population growth variables are taken from World Bank growth research data sets provided at http://www.worldbank.org/growth/index.htm. These sites expand and update the Penn World Table data sets provided by Summers and Heston (1991). Index measures of sociopolitical institutions are taken from the Freedom House annual comparative survey tables available at its web site (http://www.freedomhouse.org). Rural population density and cereal yield are obtained from the World Bank (1998) and World Resource Institute data sets (WRI, 1998), respectively.

4. THE ECONOMETRIC MODEL

The general form of the reduced form empirical model of the EKC for deforestation used in this study is given by Eqn. (1).

$$\mathrm{DF}_{it} = \alpha_i + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + \beta_4 T_{it} + \beta_5 I_{it} + \beta_6 Z_{it} + \beta_7 P_{it}, \quad (1)$$

where, $i = 1, \ldots, n$ countries and $t =$ year; DF_{it} is the deforestation in country i, year t; α_i the intercept term for country i; β_i the coefficients to be estimated; Y_{it} the GDP per capita; T_{it} the technological change; I_{it} the institutional index; Z_{it} the other macroeconomic and policy-related variables; and P_{it} is the population.

In contrast to most previous studies, which mainly focus on population growth and infrastructural development activities as the major reasons for tropical deforestation, the deforestation model presented here incorporates major macroeconomic and sociopolitical institutional factors. The deforestation process is an outcome of a complex interaction of underlying sociopolitical institutions and economic forces. Therefore, it is hypothesized that inclusion of institutional and policy factors in the regression model are required to provide reliable parameter estimates.

Compared to country specific case studies, the crossnational analysis applied here includes large variation of socioeconomic and institutional structures across countries. This facilitates identification of the net impact of institutional variables on deforestation. The other major advantage of using the panel data technique is that it gives researchers a large number of data points, increasing the degrees of freedom and reducing collinearity among the explanatory variables. Details of the advantages and limitations of using panel data methods can be found in Hsiao (1986) and Baltagi (1995).

The standard deviations of the selected variables used in crossnational comparisons are shown in Table 4 in Appendix A. For some of these, such as percentage change in cereal yield, the coefficient of variation is quite high. But to include institutional factors and the nature of the analysis requires application of crossnational data pooling, and large variations across countries is to be expected.

Simple pooled regression, as well as fixed effects and random effect models were tested to estimate the parameter values. Preliminary investigation showed that the fixed effect models performed better than the constant intercept and random effect models. The constant intercept model was rejected in favor of the fixed-effect model by the Chow test, and the random effect model was rejected in favor of the fixed effect model by significant Hausman test statistics. Econometric theory also suggests that parameters estimated from fixed-effect models are more appropriate for this type of cross-country sample analysis. The fixed effect model allows for historical and structural differences across countries by allowing each cross-section data set to have a separate intercept term but common coefficients of the selected explanatory variables (Greene, 1997).

Given the large variation of size across the countries in the sample, the fixed effect models

are estimated by weighted least square (GLS), where the weight for each observation is the reciprocal of the normalized standard deviation of the disturbance for the same observation obtained from the initial OLS estimation. Simple OLS gives equal weight to each observation. GLS corrects for some of the outliers and measurement errors by giving less weight to such outliers. The weighted least square regression results are further iterated, and converged results—iterated feasible GLS (FGLS)—are reported in Table 2. The econometric literature suggests that such iterated FGLS are equivalent to MLE estimates (Greene, 1997). Since all the observations are not available for all the countries for the 20 years, the unbalanced panel regression technique was used to accommodate the missing observations for some countries.

5. REGRESSION RESULTS AND DISCUSSION

Results of the model explaining annual percentage change in forest and woodlands area by region are given in Table 2. The institutional structure and historical patterns of resource use, and the local factors leading to deforestation process differ across countries. Individual country specific case studies provide better details of local factors responsible deforestation; however, generalization of case study results are not dependable. The cross-country-level analysis provides opportunities for such generalization of results and testing the empirical validity of conflicting theoretical propositions.

The deforestation process varies across countries and regions. For example, the main factors cited for excess deforestation in Brazil are government subsidies for livestock grazing and ranching, and subsidies for corporate forestry (Barbier, Burgess, & Markandya, 1991; Binswanger, 1991). In Costa Rica tenure insecurity and frontier colonization are cited (Southgate *et al*., 1991). In Indonesia, governmental transmigration policy, shifting agricultural practices, and timber concession rights are the major factors (Barbier *et al*., 1991). In Malaysia, it is governmental support for the logging industry (Rudel & Roper, 1997; Gillis, 1988). In West Africa (Ghana, Liberia) and in Zaire—which contains almost 10% of world

Table 2. *Factors affecting annual deforestation rate of forest and woodlands, 1972–91*[a]

Independent variable	Latin America	Africa	Asia
GDP	0.15	0.063	−0.65
	(2.83)***	(2.93)***	(3.47)***
GDP Squared	−0.019	−0.031	0.21
	(3.04)***	(3.42)***	(3.36)***
GDP Cubed	0.0008	0.0033	−0.018
	(3.21)***	(2.98)***	(3.04)***
Time	0.004	0.001	−0.008
	(8.70)***	(3.88)***	(3.47)***
Political institutions	−0.006	−0.0044	0.019
	(2.96)***	(6.10)***	(3.84)***
Black Mkt FOREX	2.2e−05	2.2e−06	0.0005
	(1.46)	(1.45)	(2.84)***
Debt	0.0003	0.0001	0.0012
	(2.55)***	(1.84)*	(3.05)***
Change in cereal yield	−4.9e−05	0.004	−0.00003
	(0.36)	(1.70)*	(0.34)
Population growth	−0.041	−0.020	0.24
	(6.81)***	(8.94)***	(3.64)***
Rural POP density	0.90	0.36	−0.014
	(4.39)***	(9.39)***	(2.78)***
Adj. R^2 (unweighted)	0.46	0.70	0.19
Number of countries	20	31	12
Number of observations	380	520	226
EKC turning points	$6,600	$1,300 & $5,000	$2,200 & $5,500

[a] Values in parentheses are absolute *t*-statistics; *F* statistics of above models are significant at 1%.

* Significant at 10%.

*** Significant at 1%.

tropical forest cover—the destruction of forest cover is due to shifting cultivation and fuelwood use caused by worsening rural and urban poverty (Gillis, 1988). Considering the historical differences and variation of deforestation processes and institutions across continents, the crossnational econometric model of deforestation is estimated on a regional basis to capture regional similarities that exist. This is plausible considering the historical pattern of deforestation processes and the development of sociopolitical institutions. For example, while the precise factors responsible for deforestation in Malaysia may vary from the factors responsible for deforestation in Indonesia; they do have general similarities and are much more closely related than the cases in Latin America or Africa. The regional models are estimated by the fixed-effect panel data analysis technique, and are supported by significant Hausman statistics. [6]

(a) *Income*

The results confirm the existence of an EKC for Latin America and Africa. Each of the income terms is statistically significant, and the quadratic income term is negative in both cases. The positive cubed term means there would be another turn in the EKC once income reaches a critical level. The curvilinear relationship between deforestation and income is observed in all three regions, though the exact shape of the EKC for Asia is different than the other two regions. The income associated with the first turning point of the curve is around US$6,600 for Latin America, which is within the sample range—close to the income of Venezuela and Argentina, and less than the income of Trinidad and Tobago. For Africa, the income associated with the first turning point is US$1,300. The mean income levels for the countries included in the analysis are US$3,500 and US$1,000 for Latin America and Africa, respectively. Thus, most of the countries in these regions are currently in the upward sloping portion of the EKC; the range of increasing forest loss.

The EKC for Asia follows a different pattern from Latin America and Africa. The signs on the GDP terms in the Asia model are opposite from the signs for the other regions. Thus, the turning points indicate changes in opposite directions. Countries with incomes up to US$2,200 show decreasing forest loss. This pattern changes over the midrange of incomes, from US$2,200 to US$5,500, where the customary decrease in environmental quality is observed. At incomes above US$5,500 the EKC slopes downward again, even to negative deforestation (net plantation) after the GDP level of US$7,750. This pattern reflects what is observed in Asia, and confirms results from other studies of deforestation in the region (Cropper & Griffiths, 1994; Koop & Tole, 1999). Negative deforestation at incomes above US$7,750 indicates that for high-income countries there would a net increase in forest and woodlands area. For low-income countries, the downward slope of the EKC indicates that forest area is declining at a slowing rate. Though natural forest clear-cutting is prevalent in Asia, particularly in Southeast Asia, reforestation is greater in Asia than the other two regions. For example, the net forest area of countries such as Bhutan, China, India, Pakistan and Sri Lanka has increased since the mid-1980s due to initiation of massive reforestation programs there. These are low-income countries falling within the initial downward sloping segment of the EKC. Higher-income countries such as Thailand and Malaysia display the classic EKC relationship of declining environmental quality as income levels rise through the middle range. Thus, though the EKC patterns and signs of regression coefficients on GDP in Asia are contrary to the results for the other regions, the EKC pattern for Asia is the same for income levels above US$2,200.

(b) *Institutions*

The political institutions variable provides insight into the impacts of institutional and political factors on deforestation. Results indicate that the impact of institutions is statistically significant and negative for Latin America and Africa. This implies that improvements in institutions that empower citizens through enhancement of democracy, strengthening of individual freedoms and civil liberties, and establishing rule of law will ultimately reduce pressure on environmental resources and lead to better conservation of forest land. Asia again provides a contrary example, likely due to the very diverse cultural and institutional settings found across the region. Countries such as Bhutan and China, where political freedom is highly restricted but reforestation programs are active, confound the results. It is also true that the development of institutions has followed a distinctly different path in Asia than in other

two regions. [7] The institutional dimension of the deforestation problem needs to be better scrutinized, especially with respect to the political economy of the EKC, since democratic institutions also emerge as societal income increases. The correlation coefficients between GDP and the institutional variables across all sample countries are relatively high compared to other variables used in the analysis. [8]

(c) *Macroeconomic and policy variables*

The black market premium coefficient is positive for all three regions, but statistically significant only for Asia. This indicates that for Asia, open trade policy and prudent exchange rate management is synergetic with managing natural resources and reduction of tropical deforestation. This is important because export of tropical logs and wood products is considered one of the prime motivations for harvesting tropical forests (Angelsen & Kaimowitz, 1999; Brown & Pearce, 1994). But, the theoretical concept of how exchange rate policy affects incentives for forest resource management is controversial. A high black market premium on foreign exchange means artificial overvaluation of the local currency and an overall economy-wide distortion. Though the coefficient of the black market premium on foreign exchange is comparatively low in magnitude in all three regional models, the results in this study support the view that removal of disincentives and lowering of economy-wide distortions will improve both economic and environmental gains, as suggested by Munasinghe (1999).

The coefficient of external debt as a percentage of total GDP is positive and statistically significant in all the three regions. Some of the recent literature on deforestation (Kahn & McDonald, 1995; Brown & Pearce, 1994) emphasized external debt as one of the main factors leading to excessive deforestation. In fact, foreign debt was one of the most important macroeconomic problems of developing countries during late 1970s and early 1980s, and these results reflect that reality. Debt-for-nature-swaps and other creative financing mechanisms are advocated to protect natural forests in the tropics and to provide long-term incentives to all stakeholders. The positive sign and statistical significance of the debt variable for all the three regions confirms the importance of debt management to the tropical deforestation process.

The coefficient of change in cereal yield—a proxy for technological change in agriculture—is negative and statistically insignificant for Latin America and Asia, but positive and statistically significant for Africa. The literature of deforestation is ambiguous with respect to the impact of agricultural technology on the tropical deforestation process. The impact of improvements in agricultural technology on forest clearing cannot be determined *a priori* without detailed information regarding the type of technological change in question and the structures of the output and factor markets (Angelsen & Kaimowitz, 1999). The "intensification hypothesis" states that technical progress in frontier farming will require that forest lands be converted to agriculture, but the same technical progress in nonfrontier agriculture would reduce the pressure on land and slow the forest conversion process. Moreover, the net impact of technology also depends on the type of technological change—whether it is labor intensive or capital intensive. Technical change is indeed a complicated issue and finding an appropriate proxy, comparable across countries, is a major bottleneck for this type of crosscountry empirical analysis.

(d) *Population factors*

Despite the emphasis on population pressure as a factor affecting deforestation in previous studies (Myers, 1994; Cropper & Griffiths, 1994; World Bank, 1992; Palo, 1994; Allan & Barnes, 1985), the results here are less compelling. In this study, the population growth coefficient is significant and negative in Latin America and Africa, but positive in Asia. The sample mean level of population growth is highest in Africa, though the population pressure measured by density is highest in Asia (Table 4 in Appendix A). This could be the reason for such variation of the impacts of population across the regions. The results of this study can also be attributed to the model specification, including institutional factors and macroeconomic policy, and the estimation technique that differ from previous studies. Shifting cultivation practices in the tropics is another commonly cited leading cause of tropical deforestation (Myers, 1991; Myers, 1994; World Bank, 1992). Shifting cultivation practices are, however, closely linked with a low level of economic development, massive poverty, high population growth, and rural unemployment in frontier regions. Thus, mea-

suring the impact of overall population growth alone disguises many underlying demographic factors affecting deforestation.

Rural population density is positive and statistically significant in Latin America and Africa, but negative and statistically significant in Asia. This implies that the rural population pressure, not the overall population growth rate, is a significant factor contributing to the deforestation process in Latin America and Africa. But the case is different in Asia. Rural population density is considerably lower in Latin America and Africa than in Asia (Table 4 in Appendix A). Thus, from this study it appears that population structure and settlement policy, and the patterns of development followed in a country, are key factors affecting deforestation.

The results found here with respect to population support the findings from a review of empirical work by Templeton and Scherr (1999) on the topic of natural resource management and population pressure. Based on a survey of more than 70 empirical studies, they found no significant evidence of population pressure leading to degradation of natural resources and forest cover, and asserted that halting population growth or reducing the population density from well-settled areas might not improve land productivity and natural vegetation in those areas. It is also suggested that there is a U-shaped relationship between tree cover and population growth. That is, tree cover (or land productivity) first decreases with population growth but ultimately it improves when the cost of land relative to labor increases to a sufficiently high level. This could be due to substitution and adoption of other induced technological and institutional innovations as land becomes relatively scarce.

The population factor is complex because property rights and private land tenure institutions become restrictive only when population densities increase to such a level that land becomes scarce. The regression results obtained in these models reinforce this argument, since land is scarce in Asia compared to Latin America and Africa. Private property rights institutions and market institutions would also develop only when population grows to a critical level, and relevant resources begin to become scarce. Once population reaches that level it produces incentives to conserve natural resources. There is no incentive to strengthen private property rights enforcement and developing marketing institutions for resources having no scarcity value. The contrast between Asia and the other two regions supports this observation.

To obtain further insights into the impacts of population on deforestation, a second set of regression models was estimated. These models were specified with the same sets of explanatory variables, but global models with all sample country data from the three regions were estimated. First, both population variables were included in the model. For comparison purposes, the population variables were eliminated and the model reestimated. The explanatory power of the global model was not significantly reduced when the two population factors were removed from the model. The results from the global deforestation model reinforce the earlier findings from the regional models. That is, when we control for the sociopolitical institutions and macroeconomic policy variables, the marginal impacts of the population growth variables either diminish, or signs are reversed from what is commonly expected.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Results of this study should be interpreted cautiously since the estimated models do not represent any specific country. But, results from such crosscountry analyses are useful to help understand some of the controversial issues discussed in the deforestation literature. In this context, a crosscountry empirical analysis, focusing on a few selected policy variables across regions, provides input for further theoretical exercises, as well as better information for global environmental policy recommendations.

The above results provide confirmation of the global environmental protection concept embodied in the EKC. The particular context of this study, where the quantity of forest area is considered to represent environmental amenities, presents some complicating issues. Clearly, forest area can be reduced through harvesting for various purposes. Moreover, replanting and plantation development can increase forest area. In general, the deforestation EKC assumes that low-income countries clear forest area without replacement, or at least that the replacement rate is less than the harvest rate. As incomes grow, investment in forests, by replacing area cut for logging or establishing

plantations of forest-producing products, more than compensates for forest area lost. The nonmarket environmental service value of forest resources also increases with rising income. Likewise, the structure of the economy and energy demand patterns may change when income rises. In many countries, fuelwood energy is predominant during the early stage of development, but coal and petroleum-based fuels become more important during later stages, thereby reducing forest conversion pressure. These structural changes in the economy that emerge with rising income are key to the EKC relationship in the forest sector. The model presented here hypothesizes this process to be significantly affected by macroeconomic conditions and institutional structures.

The results from this study suggest that strengthening of sociopolitical institutions would help to flatten the EKC for deforestation and reduce the present level of tropical deforestation worldwide. The empirical model provides strong evidence that these sociopolitical institutional factors deserve close attention in the design of environmental policies affecting the forest sector. Institutional factors are usually neglected in economic models of deforestation; however, case studies have shown that institutions have important impacts on the success of environmental protection programs and halting deforestation (Southgate & Runge, 1990). The empirical analysis in this study suggests that underlying institutional factors are relatively more important for explaining the tropical deforestation process than other frequently cited factors like population and macroeconomic conditions.

Macroeconomic factors such as a country's indebtedness, and exchange rate and trade policies, reflected in the black market premium on foreign exchange, shift the intercept of the EKC. But, the net effect varies with local conditions, and the signs and the magnitudes of the coefficients on these variables differ across regions. This implies that there is no one-size-fits-all macroeconomic policy recommendation for reversing deforestation trends equally applicable to all three regions. These results do indicate that the present level of tropical deforestation is indeed significantly affected by macroeconomic policy in some regions. Therefore, prudent macroeconomic policies and fiscal programs provide the essential economic structure to foster socially beneficial resource management. These results are consistent with previous results obtained in EKC studies with different reference indicators of environmental protection.

Interestingly, when institutional structure is included in the EKC model the impact of population growth on deforestation becomes less meaningful. Rural population density is, however, still important though the direction of impact is different in Latin America and Africa than what is found for Asia. These results indicate that overall population growth is not as important to the process of deforestation as the distribution of population and institutional structures affecting the relationship between people and natural resource utilization.

NOTES

1. The recent literature on the EKC for deforestation neglects the point that Samuelson suggested the possibility of an EKC relationship in forestry in 1976. He also emphasized the institutional role in forest harvesting and planting decisions that has existed since Roman times.

2. The literature is summarized here only in relation to the studies on EKC for deforestation and for other environmental indicators. General discussion of the economics of deforestation is found in Brown and Pearce (1994) and Repetto and Gillis (1988).

3. We are grateful to an anonymous reviewer for raising this point.

4. Three countries for which data sets contained missing observations were removed from the final estimated regression model.

5. Details of the measurement of the institutional indices of political and civil rights are found in Scully (1992) and Freedom House publications at the website http://www.freedomhouse.org.

6. Significant Hausman statistics reject the random coefficient panel modeling technique as an alternative to the fixed effects technique (Greene, 1997).

7. We are grateful to an anonymous reviewer for raising this point.

8. Interested readers may contact the authors for further information on the correlation analysis, both at the regional and global levels. The correlation between GDP and political institutions is relatively higher for Latin America and Africa than for Asia.

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APPENDIX A

See Tables 3 and 4.

Table 3. *Countries selected for the analysis and their real income in 1990*[a,b]

Latin America	1990 income	Africa	1990 income	Africa	1990 income	Asia	1990 income
Argentina	4,706	Angola	678	Mauritania	791	Bangladesh	1,390
Bolivia	1,658	Benin	920	Mozam-bique	760	Bhutan	882
Brazil	4,042	Botswana	2,285	Niger	484	China	1,324
Chile	4,338	Burkina Faso	511	Nigeria	995	India	1,264
Colombia	3,300	Cameron	1,226	Rwanda	756	Indonesia	1,974
Costa Rica	3,599	Central Afr. Rep.	579	Sierra Leone	901	Korea, Rep.	6,673
Dominican Rep.	2,166	Chad	399	Somalia	775	Malaysia	5,124
Ecuador	2,755	Congo, Dem. R.	384	Sudan	757	Myanmar	611
El Salvador	1,824	Congo, Rep.	2,211	Tanzania	550	Nepal	1,036
Guatemala	2,127	Côte d'Ivoire	1,213	Togo	641	Pakistan	1,394
Honduras	1,377	Ethiopia	324	Uganda	554	Papua N. Guinea	1,425
Jamaica	2,545	Gabon	3,958	Zambia	689	Philippines	1,763
Mexico	5,827	Gambia	790	Zimbabwe	1,182	Sri Lanka	2,096
Nicaragua	1,294	The Ghana	902			Thailand	3,580
Panama	2,888	Guinea	767				
Paraguay	2,128	Kenya	911				
Peru	2,188	Liberia	853				
Trinidad & Tobago	7,764	Madagascar	675				
Uruguay	4,602	Malawi	519				
Venezuela	6,055	Mali	531				
Average income	3,360				925		2,180

[a] 1990 income is real GDP per capita (PPP adjusted 1985 constant US$).

[b] *Source*: Summers and Heston (1991), updated by World Bank Growth Researchers Team available at their web site http://www.worldbank.org/research/growth/index.htm.

Table 4. *Descriptive statistics of variables selected in the study, by region, 1972–91*

Variable	Latin America	Africa	Asia	All countries
Deforestation rate (annual %)				
Mean	1.10	0.80	0.34	0.80
SD	1.32	0.90	1.67	1.29
GDP per capita ($1,000s)				
Mean	3.5	1.0	1.63	1.9
SD	2.0	0.8	0.34	1.7
Political institutions (index 2–14)				
Mean	9.3	5	7.31	7
SD	3.0	2	2.83	3
Black Mkt FOREX				
Mean	195	103	25	117
SD	436	370	54	338
Debt				
Mean	61	65	35	57.3
SD	83	51	22	60.8
Population growth				
Mean	2.2	2.8	2.2	2.48
SD	0.8	0.75	0.5	0.78
Rural POP density				
Mean	237	337	1456	544
SD	182	225	3123	1524
Cereal yield				
Mean	1922	955	2343	1534
SD	634	4.3	1468	886
Change in cereal yield				
Mean	1.9	0.53	1.6	1.14
SD	11.25	18.9	8.6	15.12
Number of countries	20	33	13	66
Number of observations	400	660	237	1297