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Governance, economic policy, and the environmental Kuznets curve for natural tropical forests

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ABSTRACT. This paper reports the results of an empirical analysis of the relationship between income and the rate of deforestation of tropical natural forests. The inverted U-shaped relationship known as the environmental Kuznets curve is confirmed. The study focuses on the role of institutions and macroeconomic policy in the deforestation process. Results indicate that the quality of governance is an important determinant of forest resource preservation, and that rural population pressure is not as important as suggested by other studies. Agricultural technology improvement and enhanced educational attainment also lead to reductions of deforestation rates.

1. Introduction

The major objective of this study is to carry out an empirical verification of the Environmental Kuznets Curve (EKC) relationship for deforestation of natural forests in the tropics. The study focuses on income effects of deforestation rather than structural factors and governing institutions.[1] The EKC hypothesizes an inverse U-shaped relationship between indicators of environmental deterioration and economic development. During initial stages of development, some form of environmental degradation appears inevitable, but subsequent income increases will produce incentives to improve environmental quality.

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[1] The objective of this paper is an empirical verification of the EKC hypothesis for natural tropical forests, and not to construct a best-fitted global deforestation model.

The major theme of global EKC studies is to identify potential policy programs in developing countries that move economies to a sustainable development path. In other words, this research seeks to attain an optimal environmental objective without restricting the opportunity for economic growth and socioeconomic development. The goal is to find means to tunnel through the potential EKC path by managing the economy within ecological threshold limits. Thus, when the EKC is flattened, an economy can avoid potential environmental catastrophes while achieving sustainable growth (Munasinghe, 1999; Panayotou, 1995). Prudent policy can minimize the damage done to environmental systems during the development process, thus keeping environmental damage within safe limits.

Forests embody important environmental attributes including carbon sequestration, reduction of greenhouse gas emissions, and the enormous amount of biodiversity resources found in tropical ecosystems (Brown and Pearce, 1994). The UN's Rio de Janeiro conference in 1992, Kyoto conference in 1997, and 2002 Hague declaration on protection of global tropical forest reflect rising concern for tropical deforestation. However, despite this concern, annual conversion of tropical forest to other land use was about 12 million hectares worldwide between 1980 and 1995 (FAO, 1997).

Unlike the case of flow types of pollution, the presence or absence of a Kuznetian functional relationship between income and the indicator of a stock type of environmental quality, like forest cover, is not clear-cut in the literature (Arrow *et al.*, 1995; Stern *et al.*, 1996; Ekins, 1997). The available evidence based on the EKC for deforestation is mixed, and it varies depending on the sets of countries selected for the study. Some of the previous studies on economics of deforestation of forest and woodlands have established an EKC relationship for deforestation (Cropper and Griffiths, 1994; Mather *et al.*, 1999; Bhattarai and Hammig, 2001). However these studies are based on FAO data on forest and woodland areas, which not only include actual forest, but also several things like tree crop plantations, savannahs, and grasslands, which were long cleared but still under the jurisdiction of forest agencies. This leaves open the question of whether there exists an EKC type of relationship for true forest cover. The lack of a precise measure of the appropriate deforestation process is a serious limitation of previous studies on the topic. This study contributes to this debate by using recently available natural forest cover data collected by the Global Environmental Monitoring System (GEMS) and further processed and made available from the World Resources Institute (WRI).

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 area lost. Likewise, the structure of the economy and energy demand patterns may change when income rises. In many countries, fuelwood energy predominates during early stages of development, but coal and petroleum-based fuels become more important during later stages, thereby reducing forest conversion pressure. Thus, there will be a transformation in the structure of the

economy as income increases. The model presented here hypothesizes this process to be affected by macroeconomic conditions, institutions, technology, and structural factors. Analysis of plantation forest cover would add to the EKC discussion; however, our study is limited to the empirical verification of the EKC relationship for tropical natural forest cover.[2]

2. Literature

Some of the recent empirical studies on the topic of income growth and environmental quality have shown that some pollutants such as SO_2, SMP, nitrous oxides, and river water pollutants follow an inverse U-shaped functional relationship with economic growth (Shafik and Bandhyopadhyay, 1992; Shafik, 1994; Seldon and Song, 1994; Grossman and Krueger, 1995; Panayotou, 1995).

Despite these attempts to explain the EKC relationship based on economic intuition and sound theoretical foundations, there is no unanimous view among scholars as to why and how exactly the EKC relationship emerges for certain attributes and not for other environmental indicators. The problem is further complicated by not having an acceptable measure of an indicator representing a broad range of environmental quality.

Arrow *et al.* (1995) asserted that, 'An inverted-U relationship has been shown for emissions of pollutants, but is not feasible for stock resources like forest ecosystems'. They postulated that the EKC relation is less likely to hold wherever the feedback effects of forest stocks are significant, such as those involving soil and its cover, and other ecosystems. Mather *et al.* (1999) provide historical evidence of 400 years of changing forest cover in selected European countries and have demonstrated that the EKC relationship is a historical reality.

Most cross-national studies on deforestation have focused on the impact of population growth on the deforestation process (Allen and Barnes, 1985; Cropper and Griffiths, 1994; Koop and Tole, 1999; Mather *et al.*, 1999). Due to lack of consistent cross-national statistics for other major institutional and macroeconomic policy factors, these impacts on the deforestation process have been investigated in only a few studies. Barbier (1997) suggests that the indirect linkage of income growth to changes in the structure of socio-political institutions leads to feedback effects and increased willingness to pay for environmental quality through institutional changes.[3] In fact long before the emergence of EKC literature, Samuelson (1976) postulated an EKC relationship for nature conservation and forest resources due to their public good characteristics and the high opportunity costs associated with forest preservation. He also illustrated the importance of institutional impacts – induced by income growth – on the forest harvest decision.

Norton (1998), using cross-national analysis, found that deforestation is greater in nations with weak property rights. Deacon (1994) found that

[2] We believe that analyzing the structure of plantation behavior is an important aspect of the EKC for deforestation. Moreover, growing plantation forest in Europe, North America, and even in Asia after the 1980s supports the EKC hypothesis.

[3] Details on these issues are found in Barbier (1997) and Barbier (2001).

insecure ownership, political insecurity, and political revolutions were all positively related to the deforestation process. Several country-specific case studies have identified other factors for deforestation, including prices of roundwood, inappropriate road building and infrastructure development, low wages, off-farm employment, weak institutions to enforce rules and regulations, and tenure insecurity (Barbier, 1997; Burgess, 1992; Southgate *et al.*, 1991; Angelsen and Kaimowitz, 1999). Some recent micro-level institutional analyses of forest resource management in developing countries have identified the importance of institutions and governance to forest resource use decisions. For example, Gibson *et al.* (2000), based on multi-country village-level studies, reported that the combination of national, regional, and local institutions play a critically important role in the consumption of forest resources.

3. Conceptual model of the deforestation EKC

Most previous econometric studies of the relationship between deforestation and economic development controlled for population factors alone. Unlike those studies, this study first estimates EKC models controlling for selected socio-political institutions, macroeconomic policy, technological change in the agricultural sector, and population factors. It is assumed that increases in income are accompanied by improvements in socio-political institutions and improved allocation of environmental resources, which are generally public goods. Hence, it is further hypothesized that underlying institutional and policy conditions affect the relationship between deforestation and income. This study adopts the same empirical procedures employed by other EKC studies – for example Grossman and Krueger (1995) and Panayotou (1995) – but with the addition of institutional factors, structural constraints, and broad level macroeconomic variables hypothesized to affect the income–deforestation relationship.

Unlike many other indicators of environmental quality, the relationship between deforestation and income, and associated policy and institutional factors is not straightforward. As forests in most developing countries are managed under public ownership, it is likely that the EKC relationship is linked with various socio-political institutions, structural factors, and historical development processes.

3.1. Empirical models

The relationship between economic development and deforestation is analysed using cross-section time series regression, that is panel data analysis. Some studies of the EKC for deforestation have used single-period cross-sectional data (Mather *et al.*, 1999; Antle and Heidebrink, 1995), and other studies (Shafik, 1994; Cropper and Griffiths, 1994; Koop and Tole, 1999; Bhattarai and Hammig, 2001) have applied panel data techniques. The results in these studies vary depending on the type of econometric technique used and explanatory variables selected.

The impacts of institutional and policy variables can be revealed by cross-country analysis, which provides for wide variation of institutions.

Panel data analysis allows the study of dynamic as well as cross-sectional aspects of the problem, and is therefore considered better for analyzing such complex relationships, generalizing empirical findings, and conducting theoretical modeling exercises.

A generic statement or generalized validation of an hypothesis such as the EKC for deforestation would not be appropriate by conducting a single country case study.[4] Wide variation of incomes and deforestation rates provides the advantage of cross-country analysis to test the EKC relationship. Furthermore, panel data control for the country and time invariant variables. Time-series or cross-section studies alone cannot control such individual heterogeneity. Though the process of deforestation varies across countries and regions, the fixed effect panel regression technique used in this study allows estimation of common coefficients for selected variables, while allowing structural constraints to vary across the countries. Therefore, the fixed effect technique is preferred for cross-country analysis where the sample is not drawn randomly from the population (Green, 1997; Hsiao, 1986).

The empirical model adopted in this study is

$$DF_{it} = \alpha_i + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 F_{it} + \beta_4 A_{it} + \beta_5 I_{it} + \beta_6 X_{it} + \beta_7 P_{it} + u_{it}$$

where:
DF_{it} = deforestation rate for county i in period t,
Y_{it} = GDP per capita,
T_{it} = time trend,
A_{it} = agricultural sector and other structural related variables,
I_{it} = institutional variables,
X_{it} = macroeconomic policy variables,
P_{it} = population variables, and
u_{it} = random error.

The fully specified model was estimated with a complete set of policy and population variables, applying alternative specifications of the institutional factors hypothesized to affect deforestation. Different institutional specifications are separately estimated to avoid multicollinearity and to test for possible differences of impacts between the two measures of institutional quality.

The deforestation process is influenced by a complex set of factors. Controlling for institutional and policy factors in the empirical model ensures reliable estimates of the income effects on deforestation. However, the empirical models presented in this study are proxy models. Factors underlying the deforestation decision are identified in the models. These factors both directly and indirectly influence the proximate variables (output prices and input costs) faced by the agents (farmers and

[4] Of course, there is a trade off of reliability and predictability between cross-country and country-specific analyses, where the single country case study will provide more precise policy prescriptions.

governmental authorities) involved in the forest harvesting decision. Therefore these models represent the economic and institutional context within which the markets for forest products operate.

3.2. Data

The relationship between the deforestation rate and income is examined for 63 countries from the tropical regions of Latin America, Africa, and Asia during the period 1980–1995. This includes 20 countries from Latin America, 31 from Africa, and 12 from Asia that fit the geographical restriction and for which consistent and comparable data are available. Institutional data on governance are not available for several countries in Africa; therefore, the regression models including the governance variable are estimated for only 55 countries.

Detailed descriptions of the explanatory variables are given in table 1. There is no unanimously accepted data source for measurement of tropical forest as such. Past studies of the economics of deforestation have used FAO statistics on forest and woodlands to derive the deforestation rate (Cropper and Griffiths, 1994; Koop and Tole, 1999; Bhattarai and Hammig, 2001). This study provides a comparison with previous efforts by specifying a model with a different definition of forest area provided by WRI.

Natural forest

Cross-country statistics on natural forest cover have recently become available for the years 1980, 1990, and 1995 (WRI, 1998–99). This is the natural forest cover observed by the Landsat satellite and verified using GIS and field observation data and compiled by the Global Environmental Monitoring Systems (GEMS) and FAO. The WRI data on forest are the best available cross-country comparable data on natural forest available today. However, unlike FAO data on forestry, the WRI data are available only for three points in time, 1980, 1990, and 1995. Therefore, only two deforestation periods are represented by WRI forestry data (1980 to 1990 and 1990 to 1995).

Annual deforestation rates are calculated for each of these two time periods. This deforestation term is negative if the reforestation rate is higher than the deforestation rate. Annual averages of other explanatory variables were also calculated to construct a consistent data set. That is, two observations for each country were used for the panel estimations by constructing one annual average observation from 1980 to 1990, and another annual average from 1990 to 1995.

Income

Purchasing power parity adjusted GDP per capita, in 1990 US dollars, is used as the national income measure. These data are obtained from the Summers and Heston (1991) data sets, which have been expanded by The World Bank's research groups up to 1997. It is expected that the coefficient of the GDP per capita term should be positive, and the coefficient of the quadratic GDP per capita term should be negative. Due to the limited

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

Explanatory variable	*Unit*	*Description*	*Expected sign*
GDP	US$1000	PPP adjusted per capita GDP 1985 US dollars (1 year lag)	Positive
GDP squared			Negative
Population growth	%	Annual percentage population growth rate (1 year lag)	Positive
Rural pop. density		Rural population per 1000 square km	Positive
Political Institutions	index	Sum of political rights and civil liberties indices (2–14)	Negative
Governance		Sum of indices of rule of law, bureaucratic quality and corruption in government (3–18)	Negative
Change in cereal yield	%	Annual percentage change in cereal yield	No prediction
Debt/GDP	%	Measure of debt burden in the economy	Positive
Sec. school enrolment	%	Percentage of eligible adult population enrolled in secondary schools	Negative
Economic growth rate	%	Annual percentage change in GDP per capita adjusted for inflation and population growth rates	Negative
Terms of trade	index	Terms of trade (goods and service, 1995 = 100)	No prediction
Forest area		Forest area per capita	No prediction

Source: 1. Deforestation rate is derived from change in natural forest area (WRI, 1998–99).
2. The macroeconomic variables GDP, Black mkt FOREX, Debt/GDP, Inflation rate, and Economic growth rate are obtained from the World Bank Growth Research Datasets, provided at http://www.worldbank.org/growth/index.htm.
3. Population growth, Rural pop. density, Sec. school enrollment, and terms of trade are obtained from The World Bank's World Development Report CD Rom data sets (1998).
4. Cereal yield statistics are obtained from the World Resource Institute data sets (WRI, 1998–99).
5. Indices included in Political institutions are obtained from Freedom House at http://www.freedomhouse.org/
6. Indices included in Governance are obtained from the Political Risk Services Group of IRIS, University of Maryland.

number of observations on the deforestation rate, only the quadratic form of the EKC models was estimated.[5]

[5] We also tested the cubic form of each model, but the cubic term in most of these models was not statistically significant, so final models were estimated only with the quadratic form.

Institutions

Two different institutional indices are included in the EKC model. One, Political institutions, represents democratic access (sum of political rights and civil liberty indices), as compiled and reported by Freedom House. The other, Governance, represents the quality of governing institutions, which is more concerned with the functioning of these institutions. This includes practice of impartial rule of law, quality of government bureaucracy, and corruption level in the government.

The political institutions variable is created by summing political rights and civil liberties indices obtained from Freedom House publications described by Scully (1992) and Gastil (1987). Each index has a value from one to seven and is based on a list of specific criteria. They are published in the Freedom House yearly publications.[6] The original Freedom House political rights index value is one for countries with the most political freedom and seven for the least political freedom. However, for consistent interpretation of the regression results and to have a comparable outcome with other variables, these indices are reversed in order so that the higher number indicates more political freedom and a higher level of civil liberty. Summing these two indices creates the Political Institutions variable, which ranges from two to 14. The cardinal measure of the index rather than an ordinal (or dummy variable) allows us to better quantify the impact of marginal improvement of institutional factors on the deforestation process.

The governance variable is created by summing three different indices compiled by the Center for Institutional Reform and the Informal Sector (IRIS) and published by the Political Risk Services Group, a private consulting firm engaged in international risk assessment for foreign investment.[7] The governance variable is created by summing values of indices for rule of law, quality of bureaucracy, and corruption level, mostly related to functional quality and governing institutions. All three have values one through six, so the composite variable takes on values three through 18. Details of the IRIS indices are given in Knack and Keefer (1995). Panayotou (1997) used these same data in his EKC study. The term governance refers to the manner in which power is exercised in the management of a country's economic and social resources for development and other activities (Isham *et al.*, 1997). The same applies to the quality of governmental forest authorities and their functioning for management of forest resources. It is expected that improvement in the institutional variables will have negative impacts on the deforestation rate, thus lowering the EKC for deforestation.

Agricultural sector growth

The relationship between growth of the agricultural sector and deforestation is captured by tracking improvements in agricultural productivity. Productivity changes affecting cereals production is hypothesized to reduce

[6] Details of the political rights and civil liberty indices are found in Scully (1992) and Freedom House publications at the website, http://www.freedomhouse.org.

[7] The Center for Institutional Reform and the Informal Sector is located at the University of Maryland, College Park, Maryland, USA.

the need to clear forest areas for agriculture. Improved agricultural income is hypothesized to provide income-generating opportunities for rural populations as a substitute for extraction of forest resources.

Macroeconomic policy, structural factors, and population
The macroeconomic policy variables selected for the empirical model are foreign debt as a percentage of GDP and annual growth of per capita GDP. The structural variable secondary school enrolment is also included. The population factors used in the model are population growth rate and rural population density.

3.3. Results and discussion
The results from the synthesis EKC models as reported in table 2 confirm the Kuznetian relationship for the deforestation process. That is, the inverted U-shaped relationship between deforestation and income is observed in the case of natural tropical forest, thus confirming the results found in forest and woodlands EKC models in previous studies (Cropper and Griffiths, 1994; Mather *et al.*, 1999; Bhattarai and Hammig, 2001). In addition, the adjusted R-squares of these models are sufficiently high to suggest the overall explanatory power is higher than reported in previous literature.

To better understand the impacts of the institutional variables, alternative specifications of the institutional impacts are explored. Model 1 in table 2 is specified with the governance variable, model 2 is specified with the political institutions variable, and model 3 is specified with governance and an interaction term associating governance and income to capture the effects of feedback between income development and institutional improvement on the deforestation process. This feedback effect is a missing caveat in the deforestation literature, and is also a neglected in the EKC literature for other environmental indicators. The coefficient of the governance variable is negative and statistically significant in model 1. This implies that improving the quality of governance will lower the deforestation level of natural forests in the tropics, *ceteris paribus*. This result is consistent with the fact that most natural forest worldwide, including more than 90 per cent of the natural forest in the tropics, is under the direct control of government authority. The political freedom variable is negative but not statistically significant, suggesting that it is not merely political freedom but how governance is actually performed that matters most for the preservation of the tropical forest.

The net impact of government institutions on management of natural resources is isolated from the income effect by introducing the interaction of the governance and GDP variables in model 3. The positive and significant coefficient of this interaction term indicates that the income effect on deforestation depends on the level of institutional development and vice-versa.[8] This result also indicates that improved governance fosters better management of forests and the natural environment even at lower income levels, *ceteris paribus*. Hence, the institutional impact will be relatively

[8] The authors are grateful to an anonymous reviewer for suggesting this approach.

Table 2. *Kuznets relationship for the annual deforestation rate of natural tropical forest*

Independent variable	*Model 1*	*Model 2*	*Model 3*
GDP	1.08	1.02	0.93
	(6.08)***	(6.38)***	(4.17)***
GDP squared	−0.076	−0.071	−0.078
	(5.48)***	(5.08)***	(3.82)***
Governance	−0.028		−0.056
	(3.02)***		(3.04)***
Political institutions	–	−0.0066	–
		(1.21)	
GDP* governance	–		0.000011
			(1.66)*
Economic growth rate	0.0034	−0.021	0.0022
	(0.56)	(6.71)***	(0.31)
Debt/GDP	0.0011	0.00065	0.00054
	(2.21)**	(1.61)	(0.95)
Change in cereal yield	−0.046	−0.028	−0.038
	(9.81)***	(7.42)***	(6.11)***
Sec. school enrolment	−0.024	−0.023	−0.019
	(6.56)***	(6.85)***	(3.98)***
Population growth	0.52	0.12	0.47
	(10.85)***	(2.04)**	(8.58)***
Rural POP density	−0.00009	−0.00021	−0.00007
	(2.79)***	(10.22)***	(2.47)**
Forest area per capita	−0.13	−0.004	−0.14
	(4.19)***	(0.14)	(4.83)***
Adjusted R^2 (unweighted)	0.67	0.67	0.66
Number of countries	55	63	55
Number of observations	108	124	108
EKCs turning point	$7,080	$7,140	$5,940

Note 1. Values in parentheses are absolute t-statistics; * = significant at 10%, ** = significant at 5%, *** = significant at 1%. F-statistics of above models are significant at 1%.
2. All models were estimated as fixed effects panel regressions using GLS.

strongly felt at lower income levels. But, at higher income levels, the institutional impacts may be counterbalanced by the income effect. Hence, there is an equal need to focus on the building or strengthening of governing institutions to mitigate tropical deforestation.

The statistically significant and negative coefficient of the governance variable in model 3, even when controlling for the interaction effect between income and governance, provides further evidence of the importance of governmental institutions and quality of implementing agencies and impartial rule of law in the tropical deforestation process. These results are plausible considering the real world evidence. The results here also suggest that focus on improvement in governance, including forest institutions, is important to the better management of tropical forest. Therefore, environmental policy in general is influenced not only by economic

development policy, as the basic EKC suggests, but also indirectly by institutional feedbacks, as suggested by the results of this model. These results are consistent with previous empirical studies on the topic of institutions and development, which have reported that increasing citizens' voice and public accountability – hence improved governance – can lead to greater efficacy of government action and better performance of development projects (Isham *et al.* 1997).

Deacon (1994 and 1999), Barbier (2001), and Bhattarai and Hammig (2001) have also shown the importance of institutional factors to tropical deforestation using FAO statistics on forest and woodlands, but not in the EKC framework of analysis for natural tropical forest. This study extends the institutional hypotheses of deforestation to the actual tropical forest and demonstrates the importance of institutional factors to tropical forest management, which remains a neglected issue in the deforestation literature in general and the literature of the EKC for deforestation in particular.

There are no major sign changes between models 1, 2, and 3, except for the economic growth variable. It is not significant when controlling for governance, but is negative and statistically significant when controlling for political institutions. This could be due the fact that economic growth and the effect of governance go hand in hand, and the governance variable dominated the impact of economic growth in model 1.

The coefficient of external debt is positive in all three models, as would be expected, but it is statistically significant only in model 1. Debt relief policy for the least developed tropical countries is a frequently discussed global public policy issue (Kahn and McDonald, 1995), and it is currently gaining much importance in the developmental banks' lending programs. Debt-for-nature swap programs supported by international NGOs are commonly suggested as a solution for the conservation of tropical forest ecosystems. Supporters of debt-for-nature swaps argue that these programs provide a financing mechanism and an incentive for long-run protection of tropical rainforests. The statistical results found here support this approach for conserving the tropical natural forest ecosystem.

The percentage change in cereal yield – a proxy for agricultural technology change – is negative and statistically significant in all three models. These results suggest that an improvement in the cereal yield, that is an overall improvement in technology in the agricultural sector, will halt the degradation of natural resources in the tropics. The existing literature on the role of agricultural yield performance in tropical deforestation is mixed. Angelsen and Kaimowitz (1999), based on review of more than 140 empirical studies on deforestation, reported no conclusive evidence to relate agricultural yield improvement and deforestation. Results vary by regions and local conditions. However, the empirical results in this study provide evidence of the beneficial role of agricultural intensification in managing tropical natural forests. These results demonstrate that modernization of the agricultural sector provides incentives to preserve natural forests in the long run *ceteris paribus*, thus reinforcing the EKC hypothesis for deforestation.

The secondary school enrolment variable is negative and statistically significant in all models. This implies that an improvement in education

and human capital ultimately reduces pressure on natural forests in the tropics. Based on a limited number of studies dealing with education policy and its impacts on environmental management issues, there is no a priori expectation for the sign of the education variable in a deforestation model. However, the negative sign obtained in all models is consistent with recent studies on the social aspects of deforestation issues (Ehrhardt-Martinez, 1998) and micro-level studies in Latin America (Godoy *et al.*, 1998).

Improved education could also mean increased possibility of off-farm work and/or flexibility of labour movement from rural to urban areas. In an institutional sense, education may also infer better enforcement of laws and regulations, better public participation in the political process, and better environmental awareness. Education enhances human capital, which facilitates adoption of improved technology. In addition to these factors, the education variable here may also be capturing some of the impacts of the skewness of income inequality,[9] since education counters the impacts of income inequality in an economy. Extremely skewed income inequality is considered one of the leading causes of excessive deforestation in Latin America (Binswanger, 1991).

The coefficient of the population growth rate variable is positive and statistically significant in all models. This implies that population pressures have increased the deforestation of natural forests, which is consistent with the commonly accepted notion that population growth speeds the environmental degradation process. However, to further investigate the impacts of population, a rural population density variable was also separately introduced in the model. Interestingly rural population density, which measures the local population pressure on natural forest cover, is negative and statistically significant for all three models. This suggests that deforestation of natural forest is currently at least not taking place in the regions where rural population pressure is already high, but the reverse. The opposite signs of the two population variables in the model suggest that the deforestation of natural forest is driven more by urban population growth and other structural and institutional components of the economy rather than rural population pressure. This contradicts Myers (1991 and 1994) and Palo (1994) who attribute tropical deforestation to growth of populations of peasants and frontier inhabitants. The impact of population factors on deforestation continues to be a controversial issue in the deforestation literature.

The rural population factor does not appear to be a strong cause of natural forest loss when we control for other economic, structural, and institutional variables in the deforestation model. This is in fact consistent with the real world observations, for example deforestation of natural forest in recent years was highest in Papua New Guinea, Brazil, Bolivia, Indonesia, Malaysia, Thailand, and the Philippines, where the rural population density is relatively low compared with other sample countries like China, India,

[9] An annual income inequality variable is not available for all the countries selected here; however, Sokoloff and Engerman (2000) suggest that in the long run the average education and literacy rates will be higher in a society with relatively low income inequality.

Bangladesh, and Nepal. It is possible that timber harvesting and large-scale logging by large companies in close nexus with the respective forestry agencies and other governmental institutions to share forest rent, is one of the critical causes of high deforestation rates in these countries. These observations also suggest that it is not the rural population pressure but some other broader institutional factors that drive the deforestation process in the tropics. The results found here are consistent with a few previous empirical studies on the EKC for deforestation of forest and woodlands which also reported a negative sign for the population growth factor (Shafik, 1994; Southgate, 1994; Koop and Tole, 1999).

Only two point estimates of the deforestation rate of natural forests are available for each country. Therefore, forest area per capita is included in the models to minimize the scale effect bias across the wide variation of forest areas found in the sample countries. The coefficient of the per capita forest area variable is negative in all cases and statistically significant in models 1 and 3. This suggests that the overall deforestation rate of natural forests is lower in countries with relatively high per capita natural forest coverage.

The negative quadratic GDP term was observed in all models, confirming the EKC relationship for deforestation of natural tropical forests. By solving the quadratic equation of the models, the turning points of the deforestation/income relationship can be found. The turning point income of the EKC is US$7,080 for model 1, US$7,140 for model 2, and US$5,940 with the interaction term in model 3. Thus the EKC for natural forests implies that we can expect developing countries with tropical forests and incomes below US$6,000–7,000 to continue to lose natural forestlands. This level of income is roughly equal to the 1995 per capita income of Mexico and Malaysia. When incomes grow above those critical levels, results of this model suggest that conservation efforts will become more effective and the deforestation trend will reverse. However, few countries in the sample have incomes above these levels, and therefore the question of the EKC turning point will remain debatable until further evidence is discovered. For most sample countries the EKC turning point is substantially higher than current incomes. This suggests that, in the short-term, income growth alone may not be able to check the present deforestation trend in the tropics. Prudent macroeconomic policies and strengthening institutional structure are also critically important factors for slowing the tropical deforestation process.

4. Conclusions

This study contributes to the literature of the EKC in general, and the EKC for deforestation in particular. Empirical results presented here focus on the factors affecting depletion of natural tropical forests. The natural forest data, published by WRI, provide an improved definition of the deforestation process over previous studies using FAO data on forestland and woodland. Previous empirical studies of the global EKC for deforestation provide mixed evidence of the validity of the deforestation EKC relationship. This study confirms the EKC for deforestation in tropical natural forest in developing countries and asserts that quality of institutions plays a vital role in the protection of forest resources.

Results of this study should be interpreted cautiously since the estimated models do not represent any specific country or locality where deforestation activities are taking place. However, the results from cross-national analysis are useful for validating or refuting some of the controversial theoretical and generic issues discussed in the literature. For example, what factors are the leading causes for tropical deforestation, and what global policy agendas can be adopted to halt this process most effectively? Cross-country empirical analysis provides information for global policy recommendations as well as inputs for further theoretical exercises on the subject. The results in this study provide confirmation of the global environmental protection concept embodied in the EKC, and the importance of policy and institutional factors for flattening the curve.

The EKC model for natural forest confirms that quality of governance is one of the critical determinants of tropical deforestation. Likewise, macroeconomic policy factors are also important for determining the deforestation process. Despite the emphasis given to local population pressure, shifting cultivation, and slash and burn agriculture in the literature on the economics of deforestation, it appears that local population pressure is not a primary driving force for the depletion of natural tropical forests. However, overall population growth does have a positive impact on deforestation.

The change in cereal yield and secondary school enrolment – proxies for technology change in the agrarian sector and human capital development, respectively – were both found to deter the deforestation process. Thus, at least in the long run, there will be positive feedback effects of development through improvement in the cereal yield, schooling, and other social institutions. Improvements in education provide opportunities for off-farm employment, facilitate technology adoption, and improve public participation in the democratic process. Thus, the empirical evidence from this study demonstrates that both technological and social development will have favourable impacts on the conservation of natural forests.

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