Author: Culas, Richard J
Email address:- rculas@csu.edu.au
Year:- 2007
Title: Deforestation and the environmental Kuznets curve: An institutional perspective
Journal Ecological Economics
Volume: 61
Issue: 2-3
Pages: pp429-437
ISSN: 0921-8009
Abstract: Institutions for secure property rights and better environmental policies for moving the system towards a sustainable growth path can reduce the height of an environmental Kuznets curve (EKC) relationship between income and deforestation. This study examines the impact of these specific institutional factors on the EKC relationship for deforestation across Latin American, African and Asian countries. The factors related to agricultural production, population, economy and governmental policies of each country are hypothesised to affect deforestation. Results of the Latin American countries show significant evidence of an EKC relationship for deforestation and also relevance of the institutional factors to reduce the rate of deforestation. Improvements in institutions for secure property rights and better environmental policies can thus significantly reduce the rate of deforestation without hindering the level of economic growth. Evidence also suggests that the effect of agricultural production on deforestation could be halted by strengthening institutional factors. There was found to be complementarity between the institutional factors and forest sector polices, and an additive effect between the institutional factors and forest products export promotion policies, which could also eventually reduce the rate of deforestation.

Deforestation and the environmental Kuznets curve:

An institutional perspective

Richard J. Culas*

School of Agricultural and Veterinary Sciences

Charles Sturt University, Australia

* For correspondence: School of Agricultural and Veterinary Sciences, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW 2678 Australia. Telephone: +61 2 6933 2129; Fax: +61 2 6933 2812

E-mail: rculas@csu.edu.au

Abstract

Institutions for secure property rights and better environmental policies for moving the system towards a sustainable growth path can reduce the height of an environmental Kuznets curve (EKC) relationship between income and deforestation. This study examines the impact of these specific institutional factors on the EKC relationship for deforestation across Latin American, African and Asian countries. The factors related to agricultural production, population, economy and governmental policies of each country are hypothesised to affect deforestation. Results of the Latin American countries show significant evidence of an EKC relationship for deforestation and also relevance of the institutional factors to reduce the rate of deforestation. Improvements in institutions for secure property rights and better environmental policies can thus significantly reduce the rate of deforestation without hindering the level of economic growth. Evidence also suggests that the effect of agricultural production on deforestation could be halted by strengthening institutional factors. There was found to be complementarity between the institutional factors and forest sector polices, and an additive effect between the institutional factors and forest products export promotion policies, which could also eventually reduce the rate of deforestation.

Keywords: Deforestation; Environmental Kuznets Curve; Institutions

1. Introduction

Tropical deforestation is one of the most serious environmental problems in recent times. It has become an issue of global concern because of the relevance of tropical forests in biodiversity conservation and in limiting the greenhouse effect. Deforestation also affects economic activity and threatens the livelihood and cultural integrity of forest-dependent people at the local level. It reduces the supply of forest products and causes siltation, flooding and soil degradation. Tropical rain forests, in particular, constitute approximately 41 percent of the total tropical forest cover on the land surface of the earth. Furthermore, tropical rain forests are the richest and the most valuable ecosystem providing habitation for between 50 and 90 per cent of all species on earth (WCED, 1987). During the 1980's approximately 15.4 millions hectares of tropical forests were lost annually (FAO, 1992) and the annual loss was at 12.7 million hectares between 1990 and 1995 (FAO, 1997)[1]. Tropical deforestation accounts for about 25 per cent of the heat trapping emissions at global level (Houghton, 1993).

Tropical deforestation occurs mostly in developing countries where the level of development and the welfare of the citizens are crucial factors in determining the extent

[1] The reliability of the FAO *Tropical Resources Assessment* (1992) estimates on the loss of forest area is questionable because of the poor definition and the data used (Rudel and Roper, 1997). Further, it is also dubious as to whether the annual reduction in the loss of forest area between the periods 1990-1995 is a

of the deforestation. Poverty, over-population and external debt accentuate deforestation in many of the low-income tropical countries. The requirement for economic growth and the expansion of income result in increasing the demand for agricultural and forest products. This trend is, however, unlikely in many developed countries where a higher level of (national) income growth leads to changes in the composition of the demand for goods and services, with greater demand for environmental services. This trend is characterised in recent literature as an inverted-U shaped Kuznets curve relationship between income growth and environmental quality (Grossman and Krueger, 1995). This is known as the environmental Kuznets curve (EKC). The inverted U-shaped relationship between income growth and deforestation is also noted as forest transition hypothesis (Mather, 1992; Grainger, 1995).

A theoretical exploration of the EKC for deforestation is provided by Lopez (1994). The implication of the model is that if the stock effects of forest resource (biomass) on agricultural production are internalised then economic growth, in a typical developing country, results in less deforestation (ie. following an inverted U-shaped EKC path). If these were the case, the internalisation would be induced by government policy, contractual arrangements among producers, or by the institution of individual private property ownership. The implication of this inverted U-shaped EKC is that, at an initial stage, an increase in income will accelerate the rate of deforestation, but that an income beyond a certain level (ie. the turning point) will reduce the rate of deforestation.

---

representation of a slowdown in the rate of actual forest clearance, or if a new definition and better data is used by the FAO (Angelsen and Kaimowitz, 1999).

There are also other driving forces behind the inverted U-shaped EKC relationship. These driving forces could be related to an attraction of off-farm employment to keep people away from forestland, a higher value placed on pristine forest by the public, and the government capacity to enforce forest protection through institutional factors. Several authors claim to have found empirical evidence supporting an EKC relationship for deforestation in the context of Latin America, Africa and Asia (Cropper and Griffiths, 1994; Koop and Tole, 1999; Bhattarai and Hammig, 2001). The effectiveness of the above driving forces behind the EKC relationship, in terms of government capacity to enforce forest protection through institutional factors, would decide its height and convexity. More specifically, better government policy programs will be flattening the EKC with reduced height for moving to a sustainable growth path (Munasinghe, 1999).

Although several studies have tested an EKC for deforestation, the quantitative models of deforestation have rarely examined the effects and quality of environmental policies and institutional arrangements for secure property rights on deforestation. A few studies that have examined the role of institutions on deforestation lack data that directly bears on the security of property rights or on the institutions that protect property rights. These studies have relied upon measures of political instability such as coups, revolutions and political assassinations (Deacon, 1994), or Gastil indices of political freedom and civil liberties (Bhattarai and Hammig, 2001). These sets of variables, however, capture only some of the many aspects of property rights and contractual arrangements. Knack and Keefer

(1995) provide several reasons for why such institutional measures only partially reflect the variation in property rights security among countries.

In particular, the Gastil indices of political freedom and civil liberties, as used by Bhattarai and Hammig (2001) are aggregate indicators without any explicit reference to security of property rights. They embody only some consideration of the security of property rights and contain other dimensions such as the freedom of religion and the rights of worker associations. Therefore, these indicators are likely to embody considerable measurement error in evaluating the institutions, which are thought to affect property rights, contracting rights, and the efficiency with which public goods are allocated (Knack and Keefer, 1995). In this respect, our study focuses on alternative institutional indicators of the contract enforceability of governments and the efficiency of bureaucracy as proposed by Knack and Keefer (1995). Panayotou (1997) has used these indicators as proxies for secure property rights and better environmental policies in the case of ambient sulphur-dioxide (SO_2) levels for flattening the EKC and reducing the environmental price of economic growth. However, the relevance of such indicators appears to be more appropriate for analysing an EKC for natural resource degradation such as deforestation.

Section 2 of this paper reviews the literature on the institutional aspects related to deforestation and the EKC. Data and model specification for this study are discussed in section 3. Section 4 presents the econometric models and the method of estimation.

Results and discussion are given in section 5, which is followed by a conclusion in section 6.

2. Institutions and the income-environment (EKC) relationship

Institutions are constraints that structure political, economic and social interaction. They consist of both informal constraints (such as sanctions, taboos, customs, traditions and codes of conduct) and formal rules (such as constitutions, law and property rights).[2] Creating appropriate institutions would reduce uncertainty in exchange and result in reduced transaction and production costs.[3] Institutions will improve allocative efficiency and the feasibility of engaging in economic activities. Thus, institutions are the core of the incentive structures of an economy, and as that structure evolves it shapes the direction of economic growth (North, 1991). Institutions determine our choices and provide incentives and therefore are important for the sustainable use of natural resources and better environmental quality.

---

[2] North (1981, chap 15) further distinguishes between institutions at three levels: constitutional rules, operating rules (or institutional arrangements created within the constitutional rules such as property rights regimes) and moral behavioural codes (alternatively labelled ideology, culture or cultural endowments).

[3] Institutions together with the technology employed determine transaction costs. This is as the transformation of the inputs of land, labour, and capital into the outputs of goods and services is a function not only of the technology employed, but of institutions as well. Therefore, institutions play a key role in the costs of production.

Property right regimes, in particular, are important factors in institutional analysis (North, 1991). This is as in the traditional neoclassical paradigm, with perfect information (i.e. zero transaction costs), the value of the property that is transferred assumes not only perfect information but perfectly secure property rights as well. It takes, however, resources to define and protect property rights and to enforce agreements. North (1990, p. 54) asserts that “the instability of societies to develop effective, low-cost enforcement of contract is the most important source of both historical stagnation and contemporary underdevelopment in the Third World…” because the absence of secure property and contractual rights discourages investment and specialisation. Property rights determine who can participate in decision making and ultimately use resources. For example, a subsidy or tax cannot be defined independently of property rights. Thus, well-defined property rights could lead to efficient resource use (Bromley, 1995).

The government macroeconomic policies, including monetary and fiscal policies, domestic and international trade policies have unintended adverse effects on the conservation and use of natural resources. Recent case study findings across developing countries indicate that there is a strong link between macroeconomic policies adopted by governments and environmental deterioration such as deforestation and biodiversity loss (Barbier *et al*, 1995; WRI, 2000)). In most cases, institutional failure, such as ill-defined property right regimes, is blamed for a wide set of environmental problems. A systematic discussion on this issue is also presented by Baland and Platteau (1995).

There are contradictory views on the institutional framework of property rights. Some authors argue in favour of common property resource management regimes. This debate was sparked by Hardin's "tragedy of commons" (Hardin, 1968). Ostrom (1990) summarises this debate and argues that many common property regimes have led to sustainable resource use because common pool resources have benefits from saving on high exclusion and monitoring costs. Although the common property institutions are favoured as important in natural resources management in developing countries, the success of any conservation program depends on the interests of local users and their active participation. Based on a review of several World Bank projects in developing countries, Bromley and Cernea (1989) conclude that natural resource projects ultimately fail if they do not incorporate the interests of local users. This applies also to forest resource management programs worldwide. Therefore, an essential component of sustainable development program is to create a system of incentives and sanctions (ie. institutions) across different levels (economic, political and cultural) of a society that influence the individual behaviours of those who depend upon the natural resources in question.[4]

There are extensive empirical studies on the EKC, and most of them have attempted to find an income-environment relationship for pollution and energy consumption. These

[4] A proper understanding of local community institutions is required for conservation and sustainable use of common property resources like forests and biological diversity. An institutional analysis, for proper understanding of local community institutions is therefore interdisciplinary as is perceived in most social sciences.

studies have also focused on examining possible determinants of the EKC relationship, or have investigated the impact of various conditioning variables such as trade openness (Rock, 1996a), political freedom (Torras and Boyce, 1996) and economic structure (Suri and Chapman, 1997). Also there has been an attempt to find a relationship between deforestation and political institutions (Deacon, 1994; Rock, 1996b; Bhattarai and Hammig, 2001), although the type of institutional variables used varies.

Deacon (1994) relates deforestation to insecure property rights for a cross-section of 120 countries.[5] This study hypothesises that insecure property rights arise from two sources- government instability (or inability to enforce ownership) and the absence of government accountability. Various proxies for general lawlessness, such as guerrilla warfare, revolution and frequent constitutional changes, are used to capture the degree of government instability. Furthermore, variables such as the type of government executive, the frequency of political purges and the non-existence of an elected legislature are used to proxy the absence of government accountability. Even though this study finds a consistent association between deforestation and government instability variables, the empirical model does not test an EKC for deforestation.

Rock (1996b) relates deforestation to the structure of the rural political economy for a sample of developing countries. He uses variables such as poverty, rural landlessness (the per cent of the rural population without land) and the distribution of land-holdings as a proxy for the state of rural political institutions. This study finds evidence for an EKC for

[5] The countries are divided into four groups by two criteria: firstly, developed and developing countries, secondly, high and low rates of deforesting countries.

deforestation. The results mainly indicate that policies that intensify small-scale agriculture can slow down the effect of population pressure on forests but that this outcome depends on the distribution of landholdings and the extent of rural landlessness.

The study by Bhattarai and Hammig (2001) evidences that improvement in political institutions and governance significantly reduces the rate of deforestation, and shifting the EKC for Latin America and Africa regions downwards. The institutional variable used in this analysis is a combination of political rights and civil liberty indices. The cardinal measure of these indices allows for quantifying marginal impacts of the improvement of institutional factors on deforestation. These results imply that improvements in institutions that empower citizens through the enhancement of democracy, the strengthening of individual freedom and civil liberties, and the establishment of a rule of law will ultimately reduce pressures on environmental resources and lead to a better conservation of forest land.

3. Data and model specification

Our sample consists of a total of 14 tropical developing countries from Latin America, Africa and Asia for the period of 1972-1994. The list of countries for the three regions (along with the period of data availability) is presented in Appendix 1. Due to lack of data for the institutional variable, the regional samples are restricted to 5 countries in Latin America, 4 countries in Africa, and 5 countries in Asia. Also the data for the three regions is unbalanced with 91 observations for Latin America, 53 for Africa and 102 for Asia.

(a) Rate of deforestation (forest area definition)

Forests and woodland is used to estimate the rate of deforestation. Incommensurable definitions of forest area by different sources have made comparisons of deforestation estimates difficult (Allen and Barnes, 1985) and have made it difficult to establish global generalisations regarding the causes of deforestation. Thus we define the rate of deforestation as the percentage annual decrease in forest area (minus the percentage change in forest area mean rate of afforestation), where forest area is forest cover that includes forests and all woody vegetation. The FAO *Production Yearbook* provides the most comprehensive definition for forest cover to include closed and open forests, woodland, plantations, and land from which forests have been cleared (deforested) but which will be reforested in the near future.

The broader definition for forests largely avoids the problems associated with inconsistencies and the use of restrictive forest definitions. This allows also for a greater versatility of measurement with respect to changes in a wide variety of forest vegetative types. The FAO *Production Yearbook* data is more reliable and covers more countries and spans a longer period than other sources. Other studies have used this data for the analyses of the EKC for deforestation (Cropper and Griffiths, 1994; Koop and Toole, 1999; Bhattarai and Hammig, 2001).

(b) Explanatory variables

Since deforestation is the result of a complex process generated by different causes at different levels, we specify the following institutional and other macroeconomic variables that are relevant for our models. A quadratic term of the GDP per capita is specified for the EKC relationship and the time trend is used as an indicator for the effects of other exogenous time dependent variables.

(i) Institutional variables

The institutional variables are meant to capture exogenously determined policies. As Panayotou (1997, p. 473) argues, they allow for both non-income driven (or conscious) environmental policy and the quality of policy-related institutions. He further adds that "countries with the same level of per capita income may consciously adopt more or less stringent environmental policies based on differences in educational level, quality of policy making institutions and bureaucracy, rule of law, etc."

Turning to the question of property rights, political instability and political and civil liberty indicators are, according to Knack and Keefer (1995, p. 208), insufficient proxies for the quality of institutions that protect such rights. More direct indicators are therefore needed to properly account for such institutions because, as has been discussed, institutions that protect property rights are crucial to investment and economic growth.

The security of property rights affects the magnitude of investment and the efficiency with which inputs are allocated. The property rights security, in turn, is dependent on various institutional aspects such as the e*nforceability of contracts, and the efficiency of bureaucracy*.

"Enforceability of contract" measures the relative degree to which contractual arrangements are honoured, scored on 0-4, with a higher score for greater enforceability. "*Efficiency of bureaucracy"* measures the speed and efficiency of the civil service, scored on 0-4, with a higher score for greater efficiency. However, the *efficiency of bureaucracy* variable appears to be similar to the *enforceability of contract* variable, because they are highly correlated.[6] We choose therefore the *enforceability of contract* as more appropriate proxy for the secure property rights and the quality of environmental policies.

(ii) Free Common Good Attitude (absolute forest area)

In developing countries forest sector and allied non-forest sector policies often encourage the general public to undervalue forest resources. Policies within the forest sector include timber concessions, low royalties and license fees, insecure land tenure and incentives for wood processing industries. The policies outside the forest sector include agricultural programs that clear land for estate crops, policies related to tax, credit and prices that stimulate private investment for competing land uses, and transmigration policies that

[6] The correlation coefficients are 0.66, 0.68 and 0.74 respectively for Latin America, Africa, and Asia.

encourage infrastructure development and resettlements of people (Repetto, 1988 cited in Kant and Redantz, 1997, p. 58).

These government policies and the physical nature of actual forest area reflect the Free Common Good Attitude (FCGA) of people towards forests. Consumption of forest derived products and clearings of forestland for alternative land uses are influenced by the FCGA. If the FCGA is stronger, the higher is the consumption of forest derived products and alternative land uses and hence, the higher the rate of deforestation. Due to a lack of any uniform quantifiable measure of government policies in developing countries, only absolute forest area is used as a measure for the FCGA (Kant and Redanzt, 1997, p. 58-59).

(iii) Comparative Advantage of Forest Products (proportion of forest area)

Exports of primary products from the forestry, agricultural and mineral sectors contribute significantly to the economic growth of developing countries. In that context, we focus our attention on the export of forest products and therefore question of Comparative Advantage of Forest Products (CAFP) over other products automatically arises. The CAFP with respect to other products depends on both the proportion of forest area to the total land area and the forest product export promotion policies. Due to limitations on the measurement of the government policies over the developing countries, only the proportion of forest area has been used to represent the CAFP (Kant and Redanzt, 1997, p. 60).

(iv) Agricultural production index

The agricultural sector plays a major role in the economies of many tropical developing countries. This sector contributes to GDP, employment and exports. The expansion of agricultural land into forests is thus considered a major strategy to increase agricultural production and income. This expansion is, however, due to two different activities of agriculture. Some individuals, known as "shifting cultivators" migrate to tropical forest areas for subsistence needs. Others, usually commercial farmers, convert forestland permanently for export crops.[7] An Agricultural Production Index (API) is therefore considered a variable to explain the effects of these activities on deforestation. The API is the aggregate volume of agricultural production in which international commodity prices are used to facilitate comparative analysis of productivity at national level (*www.fao.org*).

(v) Population density

Population pressures increase demand for forest products and alternative land uses and that causes deforestation. Also a growing population will supply abundant labour that affects the labour market by putting downward pressure on the wage rates and causing

[7] Shifting cultivators are peasant farmers who derive their livelihoods mainly from agriculture, utilise mainly family labour in farm production, and are characterised by partial engagement in input and output markets which are often imperfect or incomplete. On the other hand, commercial farmers are large-scale farmers, usually integrated into national or international markets (Ellis 1993, p. 13)

high unemployment rates that may further increase the pressure on forests. On the other hand, population pressure may reduce the rate of deforestation by innovation, inducing technological progress and institutional changes in agriculture and forestry sectors. As noted population pressures may result in increased deforestation initially but, having reached a certain level, production processes may be changed to improve efficiency, which in turn conserves the remaining forest resources (Templeton and Scherr, 1999). There is, however, evidence that population pressure would actually increase rate of deforestation (for example, Palo, 1994; Kahn and McDonald, 1995; Capistrano and Kiker, 1995). This effect by rural or overall population hypothesises that an increase in population density will lead to increased deforestation.

(vi) GDP per capita

It is predicted that a high GDP per capita may stimulate demand for agricultural and forest derived products and that causes deforestation. A high level of GDP per capita, on the other hand, may reduce the deforestation if it is demanded that forests be protected rather than depleted. The latter is the case in the past in many of developed countries where with economic development the valuation of the environmental services by forests became important. A high level of GDP per capita may reduce deforestation by other ways in tropical developing countries. For example, if there is a provision of adequate off-farm employment opportunities in the rural areas, rural to urban migration and a shift in energy requirements from wood based to other alternatives such as fossil fuels (Rudel, 1998). However, previous empirical evidences found a positive relation between per capita income and the rate of deforestation (Capistrano and Kiker, 1995; Krutilla *et al*, 1995). The GDP variable is measured in market prices (constant US$ as 1995 base year).[8]

(vii) Debt as percentage of GNP

Foreign debt is sometimes considered in the literature as one of the main causes of deforestation. The link between debt and deforestation is thought to be a myopic theorisation that excessive deforestation in the short run may be necessary to meet current constraints and past obligations (Kahn and McDonald, 1995). The same argument is forwarded in observing currency devaluations- that the devaluations, introduced as part of the structural adjustment programs, would promote the exports of forest and agricultural products but with an increased rate of deforestation (Capistrano and Kiker, 1995). Since most of the developing countries have substantial foreign debt and they service their debt through the export of forest and agricultural products, debt is considered as an explanatory variable in the models. Debt service as percentage of GNP (instead of debt service ratio to total export earnings) is used because of data availability for the period under study.

---

[8] There are other studies on the EKC that measured the GDP in market exchange rate (for a detail on such studies, see Stern, 1998). The market exchange rate may lower the income level of developing countries, and raise the income level of developed countries, relative to the PPP GDP data. That the use of market exchange rate GDP data for the developing countries may provide a turning point for an EKC at somewhat lower level of income than that for the PPP GDP data.

(viii) Export price index

Empirical evidence for the effects of export prices on deforestation remains controversial. It is expected that higher agricultural and timber prices, resulting from trade liberalization and currency devaluations, would in general increase forest clearing (Angelsen and Kaimowitz, 1999).[9] According to the scarcity hypothesis, however, a price increase would result in more deforestation in the short-run but in a long-run may provide incentives to conserve the forests rather than to deplete, such that the net effect on deforestation would be negative (Rudel, 1998, p. 539).[10]

Exports take place from one country to many countries and also with different types of forest and agricultural products. For this reason it is difficult to specify one export price of these products for each country. Further, conversion of forestland to pasture is concentrated more in Latin American countries than in Africa and Asia, where large-scale cattle ranching operations are driven for the purpose of export of meat (Tole, 1998). Due to the emphasis on the export of meat, in addition to the export of forest products, we use the Export Price Index (EPI) as a proxy for the export prices for the Latin

[9] This contradicts the claim that structural adjustment and trade liberalization policies will in general contribute to both economic and environmental gains, that is, a win-win situation as advocated by the World Bank and others (Munasinghe and Cruz, 1995).

[10] Sometimes higher export price can have an indeterminate effect on deforestation in the long run, depending on the net effect of whether forest depletion or forest conservation takes place more. This argument is also based on the assumption that there are no effective substitutes for wood and other forest products.

American countries. Prices for the individual commodities were used to drive the export price indices (IMF, 2000).

For the African and Asian countries, due to the non-availability of data on EPI for the study period and for the countries, we calculate an Industrial Round Wood Price Index (IRWPI) based on the unit export value of industrial round wood, since industrial round wood consists most of the forest products exported from these countries (*www.fao.org*). Firstly, the unit export value has been calculated using data on total value of export and total quantity of industrial round wood products. Then the unit export value has been converted into constant US$ using 1995 as the base year.

(ix) Time trend (technological change)

Time trend is used as a proxy to capture the effects of other exogenous time dependent variables such as technological change in agriculture. If a technological change in agriculture is labour- and/or capital-saving, it may free up more resources for additional farming and clear more forestland. However, if it is more labour and/or capital-intensive, it may not be likely to leave resources for additional farming and contribute to less deforestation. Based on a review of economic studies on deforestation, Angelsen and Kaimowitz (1999), find no conclusive empirical evidence for the effect of technological progress on deforestation. Therefore, sign of the coefficient of time trend can not be predicted *a priori*.

Details of the variables, their explanation, units, sources and the expected relationship with deforestation are all summarised in Table 1.

4. Econometric models and estimation

In our empirical models, rate of deforestation is defined as annual percentage change in forest area (DEF). Following the previous studies, our EKC hypothesis is also derived from a simple economic model in which there is no feedback from the environment to the economy. The linear specification of all of the variables provides regression coefficients between the rate of deforestation and independent variables, while the quadratic term of the variable GDP per capita validates the EKC hypothesis[11]. Since a panel data method is applied to our analysis, it involves both cross-sectional and time series data. In our model, we incorporate the individual country effects by α_i and the time trend by TT. The coefficients of the independent variables are represented by βs and the error term by ε_{it}. Based on these criteria, we specify our empirical model in the following way:

$$DEF_{it} = \alpha_i + \beta_1 CEG_{it} + \beta_2 AFA_{it} + \beta_3 PFA_{it} + \beta_4 POPDEN_{it} + \beta_5 API_{it} + \beta_6 GDPPC_{it} + \beta_7 (GDPPC_{it})^2 + \beta_8 DEBT_{it} + \beta_9 EPI_{it} + \beta_{10} TT + \varepsilon_{it}$$

[11] The EKC hypothesis suggests that the coefficient of the income term would be positive, while that of the quadratic term is negative in the estimated regression equation.

We estimate our model only for selected Latin American countries. But for Africa and Asia, due to limitation on data availability for EPI, we employ the variable IRWPI instead of the variable EPI in the same model. The panel data analysis applied here facilitates the identification of the net impact of the causes on deforestation. The advantages and limitations of using the panel data methods can be found in Baltagi (1995) and Hsiao (1986).

Simple pooled (constant intercept) regression, as well as the fixed effects and the random effects formulations of the panel data model were tested to estimate the parameter values. The model was estimated with correction for autocorrelation (AR1) by Cochrane-Orcutt transformation procedures involving the generalized least squared (GLS) method[12]. The estimated autoregressive coefficients for the model, with and without the institutional variable (CEG) are, respectively, -0.010850 and -0.142567. The Durbin-Watson statistics for these autoregressive coefficients are close to two, respectively, 2.0217 and 2.2851. These statistics suggest substantially that the model exhibit no first-order serial correlation and that the estimated standard errors and the significance of the coefficients of the estimated parameters in the model are reliable.[13]

[12] The panel data model was estimated by the econometric software LIMDEP version 7.0. The GLS procedure took into account that the data is panel data.

[13] No statistically significant evidences for the first-order autocorrelation, in particular, positive autocorrelation were found in the model at the one percent level of significant.

However, statistical investigation by an F-test showed rejection of the fixed effects formulation against the simple pooled regression. Also statistical investigation by a LM test showed rejection of the random effects formulation against the simple pooled regression. Hence the simple pooled regression was favoured overall for the estimated parameter values. The estimated parameter values (i.e. regression coefficients) are statistically more significant for the simple pooled regression than for the fixed effects formulation. Although the random effects formulation yields the regression coefficients which are virtually identical to the simple pooled regression coefficients.

Descriptive statistics of the selected variables used in the cross-country analyses are given in Appendix 2. It is to be noted that multicollinearity is not a problem for the variables in the sample, even though one would naturally expect that the institutional variable should be highly correlated with GDP per capita. The correlation coefficient is, however, relatively low for Latin America (0.35), but high for Africa (0.76) and Asia (0.65).

5. Results and discussion

The results for Latin America (Table 2) reveal evidence for the existence of an inverted U-shaped EKC for deforestation and the effect of the chosen institutional variable (CEG) on the EKC relationship that is shifting the EKC downwards. However, the model estimates for Africa and Asia, with the variable IRWPI, do not yield statistically significant evidences for the existence of an EKC and also for the effect of the chosen institutional variable. The results for Africa provide expected signs of an inverted U-shaped EKC and also the expected sign for the institutional variable. The results for Asia provide also signs for existence of a U-shaped EKC but with an unexpected sign for the institutional variable.

The statistically insignificant results for Africa might be due to the relatively smaller sample size as compared to Latin America. Although statistically insignificant the results for a U-shaped EKC for Asia might be due to implementation of both reforestation and afforestation programs in the Asian countries to compensate the deforestation (Cropper and Griffiths, 1994). Further, the development of property right institutions has apparently followed a distinctly different path in Asian countries than in other two regions.[14] Therefore, the effect of institutional variable seem to have unexpected sign for Asia than for the other two regions (Bhattarai and Hammig, 2001). Thus, for further discussion on the effect of institutional variable on the EKC relationship, we rely on the results for Latin America. Therefore, only the results for the Latin America are reported.

The institutional variable provides insight into the impact of secure property rights and better environmental policies. The results imply that improvement in institutions that empower people through secure property rights for forest resources and better

[14] Asia provides a contrary example due to the very diverse cultural and institutional settings found across the region. For example, countries such as Bhutan and China have highly restricted political freedom and countries such as India have highly diverse cultural system. Nevertheless, reforestation and afforestation programs are active in these countries and that confounds our results.

environmental policies, will ultimately reduce the pressure on resources and lead to better conservation of forestland. It might therefore be more effective to focus efforts for controlling deforestation by improving environmental policies and institutions rather than limiting economic growth and/or population growth. This is as such improvements are likely to have lower costs and more benefits than implementing artificial restrictions on economic growth and/or population growth (Panayotou, 1997, p. 478).

Considering the significant effect of institutional variable over the other explanatory variables in the model, the effects of agricultural production (API) disappear when the institutional variable is included in the EKC model. This implies that the effects of agricultural expansion on deforestation could be halted by strengthening the institutions for secure property rights and better environmental policy programs.

Furthermore, there is a complementary effect between the institutional variable and the variable AFA (which is a proxy for the forest and allied sector policies). That is the net effect of AFA on deforestation (conditional on other variables) is much less with the institutional variable in the model. For example, the effect of AFA on deforestation is 0.0047 hectare without the institutional variable and with the institutional variable the net effect becomes (+0.0047-2.2900) hectare which is equal to -2.2853 hectare. This result implies that secure property rights and better environmental policy programs could limit the effect of the forest and allied sector policies on deforestation.

Similarly, the institutional variable could have an additive effect with the variable PFA, which is a proxy for the effect of forest products export promotion policies on deforestation. The effect of variable PFA on deforestation becomes less with the institutional variable (with conditional on other variables). For example, the effect of PFA on deforestation is -7.661 hectare without the institutional variable and with the institutional variable the net effect becomes (-8.966-2.290) hectare which is equal to -11.256 hectare. This result implies that secure property rights and better environmental policy programs could further limit the effect of the forest products export promotion policies on deforestation.

6. Conclusion

Several studies have tested an EKC for deforestation, but the quantitative models of deforestation have rarely examined the effects of quality of environmental policies and institutional arrangements for secure property rights on deforestation. The few studies that have examined the effect of institutions on deforestation lack data that directly bears on the security of property rights, or on the institutions that protect property rights. Our study focuses on alternative institutional indicators such as the *contract enforceability of government* and the *efficiency of bureaucracy*. In addition to the institutional variables, other variables with respect to agricultural production, population, economy and government policies, are hypothesised to affect the EKC relationship.

Results for the Latin American countries show not only statistically significant evidence of an EKC relationship, but also the relevance of institutional variable to reduce deforestation, i.e. shifting the EKC downwards. Considering the significant effect of the institutional variable, which is over other explanatory variables, the effect of agricultural production on deforestation disappears when the institutional variable is included in the EKC model. Also, there is a complementary effect between the institutional variable and the forest sector polices, as well as an additive effect between the institutional variable and the forest products export promotion policies, which could also eventually limit the rate of deforestation.

The results imply that improvement in institutions that empower people through secure property rights for forests will ultimately reduce the pressure on resources and lead to forestland conservation. It might therefore be more effective to focus efforts for controlling deforestation by improving environmental policies and institutions, rather than limiting economic growth and/or population growth. The institutional dimension of the deforestation problem, however, needs to be further scrutinised as institutions with secure property rights and better environmental policies emerge as societal income increases. Thus further work is needed to fully unravel the effect of income-induced institutions and the institutions that emerge for autonomous environmental policies. However, this would require more data on environmental policies and the efficacy of environmental institutions than we have been able to obtain in this study.

Acknowledgment

The author would like to thank an anonymous reviewer for the constructive comments on this paper. An earlier version of this paper was presented at the Australia New Zealand Society for Ecological Economics (ANZSEE) conference held at University of Technology, Sydney, December 2-4 2002.

References

Allen, J.C., Barnes, D.F., 1985, The causes of deforestation in developing countries, Ann. Assoc. Am. Geogr., 75(2): 163-184.

Angelsen, A., Kaimowitz, D., 1999, Rethinking the causes of deforestation: lessons from economic models, The World Bank Research Observer, 14 (1): 73-98.

Baland, J.M., Platteau, J.P., 1995, Halting Natural Resource Degradation, Is there a Role for Local Communities. Oxford University Press, Oxford.

Baltagi, B.H, 1995, Econometric Analysis of Panel data, Wiley., New York.

Barbier, E.B., Burgess, J. C., Folke, C., 1995, Paradise Lost? The Ecological Economics of Biodiversity, Earth Scan Publications, London.

Bhattarai, M., Hammig, M., 2001, Institutions and the environmental Kuznets curve for deforestation: a cross-country analysis for Latin America, Africa and Asia, World Dev., 29 (6): 995-1010.

Bromley, D.W (editor), 1995, Handbook of Environmental Economics, Blackwell Publications Ltd, London.

Bromley, D.W., Cernea, M.M., 1989, The Management of Common Property Natural Resources: Some Conceptual and Operational Fallacies, discussion paper no. 57, The World Bank, Washington, DC.

Capistrano, A.D., Kiker, C.F., 1995, Macro-scale economic influences on tropical forest depletion, Ecol. Econ., 14: 21-29.

Cropper, M., Griffiths, C., 1994, The interaction of population growth and environmental quality, Am. Econ. Rev., 84: 250-254.

Deacon, R.T., 1994, Deforestation and the rule of law in a cross-section of countries, Land Economics, 70(4): 414-30.

Ellis, F., 1993, Peasant Economics, Cambridge University Press, UK

Food and Agriculture Organization, 1992, Forest Resources Assessment, Tropical Countries, Forestry paper no. 112, FAO, Rome.

Food and Agriculture Organization, 1997, State of the World's Forests, FAO, Rome.

Grainger, A., 1995, The forest transition: an alternative approach, Area 27(3): 242-251.

Grossman, G.M., Krueger, A.B., 1995, Economic growth and the environment, Q. J. Economics, 112: 353-378.

Hardin, G., 1968, The tragedy of commons, Science (new series), 162 (3859): 1243-1248.

Houghton, R.A., 1993, The Role of the World's Forest in Global Warming, in K. Ramakrishna and G. M. Woodwell (editors), The World Forests for the Future, New Haven: Yale University Press. Pp. 21-58.

Hsiao, C., 1986, Analysis of Panel Data, Econometric society monographs, no.11, Cambridge University Press, Cambridge.

International Monitory Fund, 2000, International Financial Statistics, Washington DC.

Kahn, J.R., McDonald, J.A., 1995, Third-world debt and tropical deforestation, Ecol. Econ., 12: 107-123.

Kant, S., Redantz, A., 1997, An econometric model of tropical deforestation, Journal of Forest Economics, 3(1): 51-86.

Knack, S., Keefer, P., 1995, Institutions and economic performance: cross-country tests using alternative institutional measures, Economics and Politics, 7(3): 207-227.

Koop, G., Tole, L., 1999, Is there an environmental Kuznets curve for deforestation, J. Dev. Econ., 58: 231-244.

Kurtilla, K., Hyde, W.F., Barnes, D.F., 1995, Urban energy consumption and peri-urban deforestation, Forest Ecology and Management, 74 (2): 181-195.

Lopez, R., 1994, The environment as a factor of production: the effects of economic growth and trade liberalization, J. Environ. Econ. Manage., 27: 163-184.

Mather, A.S., 1992. The forest transition, Area 24(4): 367-79.

Munasinghe, M., 1999, Is environmental degradation an inevitable consequence of economic growth: tunnelling through the environmental Kuznets curve, Ecol. Econ., 29 (1): 89-109.

Munasinghe, M., Cruz, W., 1995, Economy-Wide Policies and the Environment: Lessons from Experience. Environment Paper 10, The World Bank, Washington, DC.

North, D.C., 1981, Structure and Change in Economic History, Norton, New York.

North, D.C., 1990, Institutions, Institutional Change and Economic Performance, Cambridge University Press, Cambridge:

North, D.C., 1991, Institutions, J. Economic Perspectives, 5 (1): 97-112.

Ostrom, E., 1990, Governing the Commons: The Evolution of Institutions for Collective Action, Cambridge University Press, Cambridge.

Palo, M., 1994, Population and Deforestation, in K. Brown, D. Pearce (Editors), The Causes of Tropical Deforestation, UCL Press, London, pp. 42-56.

Panayotou, T., 1997, De-mystifying the environmental Kuznets curve: turning a black box into a policy tool, Environ. Dev. Econ., 2: 465-484.

Rock, M.T, 1996a, Pollution intensity of GDP and trade policy: can the World Bank be wrong? World Dev., 24: 471-4479.

Rock, M.T., 1996b, The stork, the plow, rural social structure and tropical deforestation in poor countries? Ecol. Econ., 18 (1996): 113-131.

Repetto, R., 1988, The Forest for the Trees: Government Policies and the Misuses of Forest Resources, World Resource Institute, Washington DC.

Rudel, T., Roper, J., 1997, The paths to rain forest destruction: cross-national patterns of tropical deforestation, 1975-90, World Dev., 25 (1): 53-65.

Rudel, T.K., 1998, Is there a forest transition? deforestation, reforestation, and development, Rural Sociology, 63(4): 533-552.

Stern, D.I., 1998, Progress on the environmental Kuznets curve? Environ. Dev. Econ., 3: 173-196.

Suri, V., Chapman, D., 1998, Economic growth, trade and energy: implications for the environmental Kuznets curve, Ecol. Econ., 25: 195-208.

Templeton, S.R., Scherr, S.J., 1999, Effects of demographic and related microeconomic change on land quality in hills and mountains of developing countries, World Dev., 27(6): 903-918.

Tole, L., 1998, Sources of deforestation in tropical developing countries, Environ. Management, 22 (1): 19-33.

Torras, M., Boyce, J.K., 1996, Income, inequality, and pollution: a reassessment of the environmental Kuznets curve", Ecol. Econ., (special issue on ERC).

World Commission on Environment and Development, 1987, Our Common Future, Oxford University Press, Oxford.

World Bank, 2000, World Development Indicators, Washington DC.

World Resource Institute, 2000, World Resources, Oxford University Press, Oxford.

Table 1: Details of variables

Variable	Explanation	Unit	Source	Expected sign
DEF	Rate of deforestation	Percentage	www.fao.org	
CEG	Contract enforceability of governments	Index 0-4	Knack and Keefer (1995)	Negative
AFA (FCGA)	Absolute forest area	1000 ha	www.fao.org	Positive
PFA (CAFP)	Proportion of forest area	proportion	www.fao.org	Positive
API	Index of agricultural production	Base period 1989-91	www.fao.org	Positive
POPDEN	Population density	People per hectare	www.fao.org	Positive

GDPPC	GDP per capita (in market prices)	1000 US$ (1995)	World Bank (WDI 2000)	Positive
$GDPPC^2$	GDP per capita squared			Negative
DEBT	Percentage of GNP	Percentage	World Bank (WDI 2000)	Positive
EPI	Export price index	Base year 1995	IMF (IFS 2000)	Negative
IRWPI	Industrial round wood export price index	Base year 1995	www.fao.org	Negative
TT	Time trend			No prediction

Table 2: Results for Latin America[@]

Dependent variable: annual deforestation rate of forest and woodland						
Independent	Without institution variable			With institution variable		
Variable	Pool regression	Fixed effects	Random effects	Pool regression	Fixed effects	Random effects
CEG	-	-	-	-2.425***	-2.816***	-2.481***
				(0.759)	(0.805)	(0.698)
AFA	0.465×10^{-5} **	0.278×10^{-4}	0.461×10^{-5}**	0.790×10^{-5} ***	0.181×10^{-4}	0.782×10^{-5}***
(FCGA)	(0.197×10^{-5})	(0.426×10^{-4})	(0.189×10^{-5})	(0.205×10^{-5})	(0.369×10^{-4})	(0.192×10^{-5})
PFA	-7.584**	-39.663	-7.945**	-8.110**	-31.506	-9.267***
(CAFP)	(3.719)	(29.874)	(3.880)	(3.154)	(25.958)	(3.445)

POPDEN	-3.183	-3.662	-3.301	-0.703	-4.814	-1.066
	(2.158)	(12.131)	(2.178)	(1.918)	(10.461)	(1.947)
API	0.311×10^{-1}	0.431×10^{-1}*	0.310×10^{-1}*	0.168×10^{-1}	0.214×10^{-1}	0.161×10^{-1}
	(0.192×10^{-1})	(0.223×10^{-1})	(0.178×10^{-1})	(0.171×10^{-1})	(0.202×10^{-1})	(0.157×10^{-1})
GDPPC	2.796***	0.471	2.835***	3.401***	3.034	3.568***
	(0.837)	(2.593)	(0.818)	(0.758)	(2.327)	(0.752)
$GDPPC^2$	-0.656***	-0.313	-0.660***	-0.811***	-0.748**	-0.833***
	(0.185)	(0.402)	(0.174)	(0.171)	(0.362)	(0.161)
DEBT	-0.367×10^{-2}	-0.195×10^{-1}	-0.465×10^{-2}	-0.415×10^{-2}	-0.498×10^{-2}	0.589×10^{-3}
	(0.352×10^{-1})	(0.496×10^{-1})	(0.331×10^{-1})	(0.305×10^{-1})	(0.441×10^{-2})	(0.284×10^{-1})
EPI	0.466×10^{-2}	0.571×10^{-2}	0.464×10^{-2}	0.963×10^{-2}	0.106×10^{-1}**	0.968×10^{-2}***
	(0.410×10^{-2})	(0.449×10^{-2})	(0.380×10^{-2})	(0.392×10^{-2})	(0.422×10^{-2})	(0.358×10^{-2})
TT	-0.260×10^{-1}	-0.505×10^{-1}	-0.252×10^{-1}	-0.360×10^{-1}	-0.293×10^{-1}	-0.333×10^{-1}
	(0.441×10^{-1})	(0.763×10^{-1})	(0.412×10^{-1})	(0.382×10^{-1})	(0.660×10^{-1})	(0.353×10^{-1})
Constant	-0.623	-	-0.432	3.618	-	4.298*
	(2.396)		(2.395)	(2.738)		(2.462)
df	76	72	-	75	71	-
R^2	0.184	0.207	-	0.292	0.323	-
F statistics	0.509			0.821		
(df)	(4, 72)			(4, 71)		
LM statistics	2.10			1.69		
(df)	(1)			(1)		
Hausman χ^2		1.98			2.79	
(df)		(9)			(10)	

@ Standard errors are in parenthesis.

*** Significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.

Appendix 1: List of countries

Africa	Congo Democratic Republic (1982-87), Cote d'Ivore (1978-92), Kenya (1978-84; 1990-91), Nigeria (1972-94)
Latin America	Bolivia (1984-86), Brazil (1972-94), Colombia (1972-94), Ecuador (1976-94), Peru (1972-94)
Asia	India (1972-94), Indonesia (1972-94), Malaysia (1972-94), Philippines (1972-94), Thailand (1978-82; 1990-94)

Appendix 2: Descriptive statistics of variables in the study, by region, 1972-94

Variable	Latin America	Africa	Asia
Deforestation rate (annual %)			
Mean	0.10×10^{-2}	0.61	0.23
SD	0.90	1.92	2.33
Contract enforceability of governments (index)			
Mean	1.92	1.95	1.97
SD	0.22	0.43	0.30

Total forest area (1000 ha)			
Mean	178980.81	31348.60	50651.80
SD	217312.57	48646.11	40758.79
Proportion of forest area			
Mean	0.60	0.30	0.47
SD	0.60×10^{-1}	0.17	0.18
Population density (people per ha)			
Mean	0.22	0.51	1.36
SD	0.92×10^{-1}	0.28	0.79
Agricultural production index			
Mean	84.12	78.94	81.17
SD	16.00	18.52	19.11
GDP per capita (US$1,000s)			
Mean	1.72	0.48	1.18
SD	0.99	0.30	0.95
Debt (percentage of GNP)			
Mean	6.14	8.74	5.66
SD	3.59	5.75	3.68
Export price index			
Mean	97.99	-	-
SD	32.43	-	-
Industrial round wood price index			
Mean	-	82.94	263.50
SD	-	45.54	313.97
Number of observations	91	53	102