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Chapter 3

THE UNDERLYING CAUSES OF DEFORESTATION AND THE PATTERNS OF FOREST TRANSITION: IMPLICATIONS FOR THE INTERNATIONAL REDD POLICY

Richard J. Culas*
School of Agricultural and Wine Sciences, Charles Sturt University
PO Box 883, Orange NSW 2800, Australia
International Centre of Water for Food Security, Charles Sturt University
Locked Bag 588, Wagga Wagga NSW 2678, Australia

ABSTRACT

International attention is focussed on ways to reduce deforestation because of the emerging concerns over greenhouse gas emissions and biodiversity loss. However the underlying causes of deforestation are rooted in current economic and development paradigms. This chapter looks at the reasons why deforestation occurs and its environmental aspects with respect to the level of economic development and climate change. To explore the impact of economic development on deforestation, the changing pattern of forest transition, i.e. an Environmental Kuznets Curve (EKC) relationship for deforestation, should be detailed. The forest transition patterns could assist in directing the goal of international Reducing Emissions from Deforestation and forest Degradation (REDD) policies. While addressing some common methodological issues of the cross country studies, this chapter therefore examines the relationship between deforestation and economic growth, conditional on the main underlying causes of deforestation for developing countries. The results, based on panel data analyses, show that forest sector policies and population density could increase deforestation, while some macroeconomic policies, if associated with technological progress, could decrease deforestation. An inverted U-shaped EKC empirically fits for Latin American and African countries, while a U-shaped EKC does the same for Asian countries. The estimates and the shapes of EKC for the three regions of developing countries could, in particular, direct designing the specific goals of international REDD policies for those regions.

Keywords: deforestation, underlying causes of deforestation, climate change, forest transition (Environmental Kuznets Curve), REDD.

* E-mail: rculas@csu.edu.au

1. INTRODUCTION

The large-scale depletion of tropical forest is one of the most serious environmental problems in recent times. It has become an issue of global concern because of tropical forests' relevance in limiting the greenhouse effects and biodiversity conservation. Between 1990 and 2005, forest area decreased by an average of 13 million hectares per year (excluding reforested area) (FAO, 2005), with major consequences for climate and biodiversity. Deforestation is now the second leading cause of greenhouse gas emissions, just behind industrial emissions. At global level, tropical deforestation accounts for about 25 percent of the heat trapping emissions (Houghton, 2005). Tropical rain forests, in particular, constitute about 41 percent of total tropical forest cover on the earth's land surface, and it is the richest and the most valuable ecosystem that provides habitation for between 50 and 90 percent of all species on earth (WCED, 1987). Forest depletion also affects economic activity and threatens livelihood and cultural integrity of forest-dependent people at local level.

Most of the forest depletion happens in tropical developing countries where the status of development and welfare of the citizens are crucial factors in determining the extent of the forest depletion. Poverty, over-population and indebtedness accentuate deforestation in many of the low-income tropical countries. The requirement for economic growth and expansion of income result in growing demand for agricultural and forest derived products. Such trend is quite unlikely in many developed countries where higher level of (national) income growth leads to changes in the composition of demand for goods and services, with greater demand for environmental services. This trend is characterized as an inverted-U shaped Kuznets curve relationship between income growth and environmental quality (Grossman and Krueger, 1995) or an Environmental Kuznets Curve (EKC) relationship between income growth and rate of deforestation (for example, Cropper and Griffiths, 1994; Culas, 2007; Koop and Tole, 1999).

In many cases, however, the studies of deforestation do not provide a clear picture of its underlying causes and the causes seem to vary from place to place. For example, international timber trade has played a major role in Southeast Asia but only a minor role in Latin America, whereas cattle ranches (pasture) has caused much deforestation in Latin America and little deforestation in anywhere else (Culas, 2009). Although tropical forests are mostly located in low income countries, deforestation is now a global problem due to climate change, and that developed countries are now aware that a *laissez-faire* policy for managing the tropical forests will jeopardize the future of the planet and their own development paths. In this regard the international community is actively looking for global solutions and is trying to identify policy instruments that could persuade tropical countries to curb their deforestation. The main causes of deforestation are due to the expansion of arable land, the need of local populations for fuelwood (Chomitz *et al.*, 2007), and for the need of country's foreign exchange earnings from trade in tropical timber and export crops at the expense of forest conservation. For governments of many developing countries these are the easiest and the most accessible ways to respond to their ever increasing economic pressures.

As consequences of increasing economic pressures, developing countries are not in a position to reduce their deforestation activities without compensation from the developed countries. Developing countries argue that a global solution to the deforestation issue must include a North-South financial transfer scheme to compensate for the revenue foregone, and also for the costs associated with monitoring and controlling the exploitation of their forests, for example, in a context of illegal logging by local and foreign corporations, and the corruption. However, various international mechanisms have been tested in the past and new proposals are under way such as the UN-REDD programme (Reducing Emissions from Deforestation and forest Degradation). Attempts to reach an international agreement on reducing tropical deforestation have to date achieved little despite over 30 years of UN negotiations. The reasons for the previous unsuccessful attempts are partly due to the different motivations of the economically developed, mainly previously deforested, nations who see the tropical forests as providing a global service, and the poorer, now deforesting nations, who see them as a national resource to be exploited as a means to development. Until now the financial support on offer has not been sufficient for the deforesting nations to abandon agriculture- or timber- driven development (Humphreys, 2008), and that the new REDD agreement negotiated in the UN hopefully change this situation. There is an implicit conflict between planned deforestation and climate mitigation objectives, which could be resolved with compensation to forest nations through initiatives from the REDD policies.

The REDD mechanism, a North-South financial transfer to compensate countries for avoided deforestation, may have both direct and indirect impacts on deforestation. The direct impact is due to the conditionalities of REDD instruments and the way they are designed, and the indirect impact is due to their feedback effects through the drivers (underlying causes) of deforestation such as urban and rural income, poverty rates, agricultural productivity, and foreign exchange earnings. However, the net effects of these policy instruments are not straightforward to the recipient countries. For instance, if massive payments are made, they will increase net national income. They may improve the investment capacity of rural communities or the investment capacity of the state. They may also contribute to greater foreign exchange earnings and to debt alleviation. Otherwise, the large REDD transfers can actually relieve pressure on forest resources if they are allocated to poverty alleviation programs in rural forested area (Karsenty, 2008).

On the other hand, the funds can also be used to promote activities that compete with forest cover such as the development of infrastructure (roads across forests) or the expansion of cash crops at the expenses of forest land. In such case, the indirect impact of North-South transfers might be an acceleration of deforestation in the medium and long term, annihilating short term efforts to avoid deforestation by the REDD policy. Further, given the range of international policy instruments tabled in current international negotiations, there is a need for a better assessment of their direct and indirect impacts on the drivers of deforestation, because the impact on deforestation can either be positive or negative. The objective of this paper is therefore to explore the patterns of forest transition (EKCs), conditional on main underlying causes of deforestation, across geographical regions of Latin American, African and Asian countries. The patterns of forest transition can direct designing the specific goals of international REDD policies for those regions.

The paper is organized as follows. Section 2 provides a discussion on forest transition and the international policy instruments to reduce deforestation. Section 3 details the data and model specification. Section 4 describes the econometric models and method. Results and discussion are provided in section 5, following conclusion and policy implications in section 6.

2. Forest Transition and the International Policy Instruments to Reduce Deforestation

The pressures to deforest come from wider economy and the level of economic development, not just from the forest sector. Therefore, as an economy develops, the influences change. For example, at early stages of economic development, population and demand for agricultural land rise fast and forests are often cleared to make way for farms. Additionally, Less-Developed Countries often try to increase exports of raw materials and encourage timber and other primary industries that cause deforestation. Profits from these industries create capital that is often invested in activities and transport infrastructure which fuel further deforestation. This leads to very rapid and accelerating deforestation.

Most economically developed nations cleared their forests in the 19th and 20th centuries, but since 1950s deforestation has primarily occurred in tropical developing countries. With further development deforestation could typically slow down in developing countries. This is because, as forest cover decreases, increasing scarcity and awareness of forest resources can prompt policies reducing its loss. This change from deforestation to a stable or increasing forest cover is hypothesised as “forest transition” or the Environmental Kuznets Curve for deforestation (EKC). This change can occur at income levels (GDP per capita) greater than the current levels. However, countries that do not develop as they deforest, but remain trapped in a cycle of poverty and subsistence farming (eg. Ethiopia and Haiti), often continue to lose forest cover (Rudel *et al.*, 2005). After the forest transition, forest cover remains stable (often at low levels) or gradually increases and this pattern has occurred in Europe and North America over the past two centuries (Angelsen, 2007). More recently country like China has experienced forest transition with increasing levels of forest cover where economic growth created off-farm opportunities and secured tenure policies (Xu, *et al.*, 2007). The patterns of forest transition have also implications for the goal of international REDD policy (Figure 1).

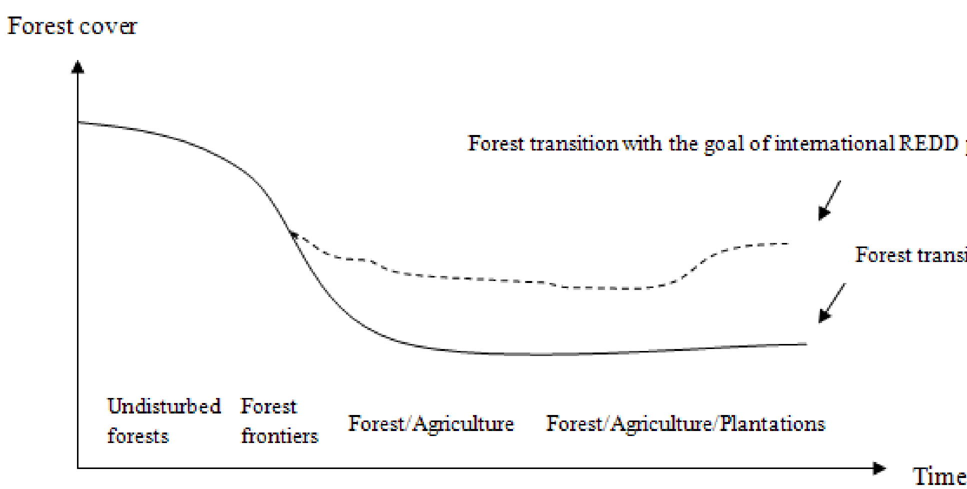

Figure 1. The forest transition and the goal of international REDD policy.

The forest transition could occur through an expansion of secondary forests and plantations, sometimes with continued loss of old growth (primary) forests as countries develop (Mather, 1992), although the secondary forests and the plantations do not have the same biodiversity and carbon storage benefits as the primary forests. When designing policies to reduce deforestation, it is useful to distinguish between "planned" deforestation which helps meet broader national policy objectives (such as poverty reduction and economic growth) and "unplanned" deforestation which does not achieve wider goals, nor bring economic benefits (Chomitz *et al.*, 2007). Halting such unplanned deforestation typically requires correction of both market and governance failures.

In a historical context, by early 1970s developed countries pressed the South to implement sustainable forest management. However, developing countries, as grouped in G77, demanded that a global forest fund be created to finance *opportunity costs foregone*, arguing that developed countries shared responsibility in tropical deforestation through their unsustainable consumption of tropical forest products. But developed countries rejected this proposal despite renewed efforts, and that all "international forest negotiations failed to resolve the issues of finance and technology to the satisfaction of developing countries" (Humphreys, 2008). However, genuine multilateral negotiation for policy instruments to reduce deforestation only started at the 11th Conference of Parties (COP) of the UN Framework Convention on Climate Change (UNFCCC) in Montreal in 2005, where proposal for a new North-South transfer mechanism was established to reduce emissions from deforestation and forest deforestation (REDD).[1]

International community has been aware of the deforestation issue since 1970s and tested several policies and instruments with mixed results. The 1992 Rio Summit successfully launched the Framework Conventions on Climate Change and on biological diversity, but negotiations on forest management again failed to reach a consensus. Five years later, the Kyoto Protocol only succeeded by including afforestation and reforestation in the Clean Development Mechanisms (CDM), as projects for the reduction of emissions in developing countries. However, this left aside the crucial issue of deforestation, and in the face of blocked multilateral negotiations, self-supporting initiatives emerged, such as the debt-for-nature swaps initiated by World Wildlife Fund (WWF) in 1984, to enable developing countries to reduce their debt while increasing their budget for conservation activities (Culas, 2008). NGOs negotiated the reduction of the debt of developing countries with international banks outside international official agreements, and in return developing countries committed themselves to an environmental conservation agreement. Another initiative by NGOs is the Forest Stewardship Council (FSC), which promotes timber product certifications to stop illegal trade and to promote sustainable forest management (FAO and ITTO, 2005). Some countries have also invested in bilateral agreements, for instance in 1998, the United States enacted Tropical Forest Conservation Act (TFCA) to offer eligible developing countries options to relieve certain official debt owed to the U.S. while at the same time generating

[1] The UNFCCC discussions for the REDD were initiated by proposals submitted by Costa Rica and Papua New Guinea and then endorsed by a large number of countries and institutions, Coalition of Rainforest Nations, at the COP 11 held in Montreal in 2005 (www.rainforestcoalition.org).

funds to support local tropical forest conservation activities (US Department of State website).[2]

Further, outside the actual international negotiations or current bilateral agreements, developing countries have also proposed groundbreaking deals to some developed countries to protect rainforest. For instance in 2007, the Government of Ecuador declared it was ready to renounce exploiting the oil resources located under Yasuni National Park if the international community compensated the loss of revenues. In the same year, Guyana offered Britain the management of one million acres of rainforest in exchange for financial transfers.[3] In 2005, Costa Rica and Papua New Guinea submitted a proposal for a multilateral REDD policy for countries that agree to reduce their deforestation and forest degradation below a baseline would be entitled to compensation from developed countries, either in the form of monetary transfers or through tradable allowances in proportion to avoided deforestation. This proposal was endorsed for the first time for the idea that forests should be considered both by developing countries and developed countries as a global public good and that the participation of all countries should be sought.[4]

After a preliminary review of the REDD proposal, international negotiations for *avoided deforestation* resumed in 2007 at the COP 13 to the UNFCC held in Bali, which focused on the urgent need to mitigate the impact of deforestation on climate change. However no consensus has yet been reached on the best mechanism and payment rules for implementing the REDD policy. The group of developing countries disagreed among them, and with developed countries, for their capacity to reduce deforestation.[5] However, a consensus has been reached among the countries as *non-binding* at the COP 15 to the UNFCC held in Copenhagen in 2009. The REDD mechanism examines two approaches, the one, *the input-based option*, seeks to manage the drivers of deforestation by paying countries that adopt deforestation mitigation policies. The other, *the output-based option*, pays countries once results in terms of avoided deforestation (either at national or at project level) can be observed and certified. The first option has an advantage because deforestation levels do not need to be measured and that developed countries can to some extent impose their preferred anti-deforestation strategies on deforesting countries. The latter option guarantees that the target of avoided deforestation is reached before payments are made. The implementation of REDD could involve very large North-South transfers, beyond current Official Development Assistance (ODA) flows, and this can make cautious attitude for some developed countries and to examine alternative approaches to the deforestation problem.

Historically there have been several types of international instruments envisaged to curb the global rate of deforestation. Those instruments can be viewed into five broader categories (i) trade instruments that sanction illegal logging (ii) forest stewardship certification with the

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[2] Nearly six countries currently have TFCA agreements: Bangladesh, Belize, El Salvador, Panama, Peru and Philippines. These agreements were adopted between 2002 and 2004 to generate an amount of $70 million for tropical forest conservation in these countries.

3 http://www.independent.co.uk/environment/climate-change.

[4] Nine countries have already expressed formal interest in receiving assistance through the UN-REDD Programme: Bolivia, Democratic Republic of Congo, Indonesia, Panama, Papua New Guinea, Paraguay, Tanzania, Viet Nam, and Zambia.

[5] The UN-REDD Programme is also working and cooperating closely with World Bank's Forest Carbon Partnership Facility; the Global Environment Facility's Tropical Forest Account; and Australia's International Forest Carbon Initiative (www.undp.org/mdtf/un-redd).

expectation that certified products will meet a greater international demand and reach a higher price than non-certified products (iii) debt-for-nature swaps (iv) input-based REDD payments, and (v) output-based REDD payments. However, the net effects of these policy instruments are not yet straightforward. The direct impacts of these instruments are linked to the way the instruments and conditionalities are designed. These international instruments have also indirect long term impacts on deforestation through its drivers (the underlying causes) of deforestation of recipient countries. For instance, if massive payments are made, they will increase net national income. They may improve the investment capacity of rural communities or the investment capacity of the state. They may also contribute to greater foreign exchange earnings and to debt alleviation. Otherwise, the large REDD transfers can actually relieve pressure on forest resources if they are allocated to poverty alleviation programs in rural forested area (Karsenty, 2008).

On the other hand, the funds can also be used to promote activities that compete with forest cover such as the development of infrastructure (roads across forests) or the expansion of cash crops at the expenses of forest land. In such case, the indirect impact of North-South transfers might be an acceleration of deforestation in the medium and long term, annihilating short term efforts to avoid deforestation. Given the range of international policy instruments tabled in current international negotiations, there is a need for a better assessment of their direct and indirect impacts on the drivers of deforestation, because their net impact on deforestation can be either positive or negative, and this has implication for the patterns of forest transition (EKC) hypothesis.

Empirical studies on the patterns of forest transition (i.e. shapes of EKCs for deforestation) provide ambiguous results. Studies of this literature tend to find evidences for existence of EKCs for deforestation but their findings vary significantly in terms of several aspects: the deforestation estimates used (annual rate of deforestation or rate of change in forest cover); the type of data used (cross-sectional or panel data); the time period of analysis (short-term or long term); the estimation techniques (simple pooled or fixed- and/or random effects regression models); the form of dependent variable (level or log form); the exchange rate for the GDP variable (market or PPP); the functional form of the GDP variable (with or without a cubic term); and the conditional or explanatory variables included in the empirical models (Stern, 1998).

3. Data and Model Specification

Many economic models attempted to identify the causes of deforestation. A review of such studies are found in Angelsen and Kaimowitz (1999) and Barbier and Burgess (2001). Some studies also attempted to test the forest transition (EKC) hypothesis however they differ with respect to their explanatory (conditional) variables and therefore the policies to reduce deforestation (for example, Bhattarai and Hammig, 2001; Combes Motel *et al*., 2009; Cropper and Griffiths, 1994; Culas, 2007). These studies justify the choice of the regional/continental division claiming that such division provides a comparable set of environmental and economic conditions across geographical areas/countries.

The forest transition hypothesis argues that it is unlikely that massive deforestation will be maintained over time, as the opportunity costs of deforestation increase with increased forest scarcity (Damette and Delacote, 2008; Ewers, 2005; Karsenty, 2008). It is also argued that the forest scarcity reduces incentives to deforest and can even lead to reforestation as evidenced in countries like China and India (Rudel *et al.*, 2005). However, in contrast to these arguments, countries like Brazil, Cameroon and Indonesia continue to deforest because of the abundance of their forests. Therefore the econometric models chosen include absolute and relative forest area variables following Culas (2007).

The sample tested consist a total of 43 tropical developing countries from African, Asian and Latin American regions covering the period 1971-1994. A list of countries for these regions is given in Appendix 1. The list excludes the Middle East oil economies and North African countries and some others. However the listed countries provide comparable set of environmental and economic conditions across the geographical areas. African sample consists of 23 countries, Asian 11 countries and Latin American 9 countries. Due to non-availability of data for some variables for the entire period 1971-1994, the data are unbalanced with 330 observations for Africa, 190 for Asia, and 199 for Latin America.

(A) Rate of Deforestation (The Dependent Variable)

Rate of deforestation is defined as the percentage annual decrease in forest area (*minus* the percentage change in forest area means rate of afforestation). Forest area is forest cover that includes forests and all woody vegetation. FAO Production Yearbooks provide the most comprehensive definition for forest cover to include closed and open forests, woodlands, plantations, and land from which forests have been cleared (deforested) but which will be reforested in the near future.

(B) The Underlying Causes (The Explanatory Variables)

Deforestation is a complex process generated by different causes at different levels (Culas, 2009). Therefore the following underlying causes that are theoretically important for the econometric models are specified. A quadratic term of the GDP per capita is specified for the EKC relationship and time trend is used as an indicator for the effects of other exogenous time dependent variables. Details of the variables, their explanations, units, sources and their expected relationship with deforestation are summarized in Table 1.

Table 1. Details of variables

Variable	Explanation	Unit	Source	Expected sign
DEF	Rate of deforestation	Percentage	www.fao.org	
AFA (FCGA)	Absolute forest area (Free Common Good Attitude)	1000 ha	www.fao.org	Positive
PFA (CAFP)	Proportion of forest area (Comparative Advantage of Forest Products)	proportion	www.fao.org	Positive
API	Agricultural Production Index	Base period 1989-91	www.fao.org	Positive
POPDEN	Population Density	People per hectare	www.fao.org	Positive
GDPPC	GDP per capita	1000 US$ (1995)	World Bank (WDI 2000)	Positive
$GDPPC^2$	GDP per capita squared			Negative
GDPG	Annual rate of growth	Percentage	World Bank (WDI 2000)	Positive
DEBT	Percentage of GNP	Percentage	World Bank (WDI 2000)	Positive
EPI	Export price index	Base year 1995	IMF (IFS 2000)	Negative
IRWPI	Industrial roundwood export price index	Base year 1995	www.fao.org	Negative
TT	Time trend			No prediction

(i) Free Common Good Attitude (Absolute Forest Area)

In tropical developing countries forest sector and allied (non-forest sector) policies often encourage general public to undervalue forest resources. Such policies within 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 encourage infrastructure development and resettlements of people (Repetto, 1988 cited in Kant and Redantz, 1997).

These government policies together with the physical nature of forest (i.e. absolute forest area) reflect the *Free Common Good Attitude* (FCGA) of people towards forests. The FCGA influences consumption of forest derived products and clearing of forestland for alternative land uses. Thus, the stronger is the FCGA, the higher will be the consumption of forest derived products and the alternative land uses, hence, the rate of deforestation. Due to lack of any uniform quantifiable measure of government policies over the tropical countries, only absolute forest area is used as a measure for the FCGA (Kant and Redanzt, 1997 cited in Culas, 2007).

(ii) Comparative Advantage of Forest Products (Proportion of Forest Area)

Exports of developing economies have been historically based on primary products of forestry, agricultural and mineral sectors, which contribute significantly to their economic growth. In the present context, the focus is on the export of forest products therefore question of *comparative advantage of forest products* over other products automatically arises. Comparative Advantage of Forest Products (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 of national governments. Due to limitations on the measurement of the government policies only the proportion of forest area has been used to represent CAFP (Kant and Redanzt, 1997 cited in Culas, 2007).

(iii) Agricultural Production Index

Agricultural sector is a major contributor to the economies of many tropical developing countries. It contributes to GDP, employment and exports. Agricultural expansion into forestland is therefore considered as a major strategy to increase agricultural production and income. Expansion of agricultural land into forestland is however due to two different activities of agriculture. Some people migrate into tropical forest areas for subsistence needs and are called *shifting cultivators*. The others who convert forestland for export crops are called *commercial farmers* (Angelsen *et al.*, 1999).[6] Agricultural production index is therefore considered as an explanatory variable to explain the effects of these activities on deforestation. This index is an aggregate volume of agricultural production in which international commodity prices are used to facilitate comparative analysis of productivity at national levels (www.fao.org).

(iv) Population Density

Population pressure increases deforestation because of ever increasing demand for forest products and alternative land uses. The growing population will also supply abundant labour that will affect the labour markets by pushing down the wage rates and high unemployment rate that may further increase the pressure on forests. Population pressure may, on the other hand, contribute to reduce the rate of deforestation by innovation, inducing technological progress and institutional changes in agriculture and forestry sectors. This means initially population pressures may cause an increased deforestation, but once the population growth reached a certain level, production processes would be changed to improve efficiency that could lead into conservation of remaining forestlands (Templeton and Scherr, 1999). Although the effect of population pressure is by rural population or overall population, it is hypothesized that an increase in population density will lead into increased deforestation.

(v) GDP per Capita (Income Level)

It is hypothesized that an increase in income level will stimulate demand for agricultural and forest derived products that can cause deforestation. On the other hand, a high income can reduce the pressure on forests if there is a demand for protection of forests. The latter is

6 Shifting cultivators are peasant farmers who derive their livelihoods from agriculture, utilise family labour in farm production, and are characterised by partial engagement in the input and the output markets which are often imperfect or incomplete. Whereas the commercial farmers are big farmers usually integrated into national or international markets (Ellis, 1993).

the case in the past in many developed countries where with economic development those countries demanded more the environmental services that provided by the forests. A high income can otherwise reduce the pressure on forests in developing countries in other ways. For instance, if there is a provision of adequate off-farm employment opportunities in the rural areas or rural to urban migration, and a shift in energy requirement from fuelwood to other alternatives such as fossil fuels (Rudel, 1998).

A relationship between deforestation and income variable can validate the presence or the absence of an EKC relationship. A quadratic form of the income variable is therefore specified in the model to test the EKC relationship. For an inverted U-shaped EKC the coefficient of the income variable would be positive while the quadratic form of the income variable would be negative. For a U-shaped EKC the coefficient of the income variable would be negative while the quadratic form of the income variable would be positive.

(vi) GDP Growth (Economic Growth)

It is expected that growth of an economy is accelerated by export of agricultural and forest derived products that causes deforestation. Once an economy grows it also catalyses the exports therefore the cause-effect relationship between deforestation and economic growth can be confusing and can lead to the problem of *simultaneity*. Although the simultaneity can be a problem for cross sectional studies, for time series studies it can be expected that an increased economic growth can lead into an increase in the exports of agricultural and forest derived products (Kant and Redantz, 1997). Further, the effects of income level (GDP per capita) and economic growth (GDP growth) on deforestation should not be in a same direction, they may vary, in particular, in long run.

(vii) Debt (Debt as Percentage of GNP)

Foreign debt is one of the main causes of deforestation (Culas, 2006). Kahn and McDonald (1995) hypothesis that the link between debt and deforestation is a myopic behavior that causing excessive deforestation in the short run, although not optimal in the long run, is necessary to meet the current economic constraint and the past obligations. Otherwise, Capistrano and Kiker (1995) hypothesis that currency 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. Debt is an explanatory variable in the model since many of the developing countries have substantial foreign debt and they service their debt through the export of forest and agricultural products. Data for debt as percentage of GNP is used in this study, instead of debt service ratio to total export earnings, because of non-availability of data for the entire study period.

(viii) Export Price Index

The effect 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. According to *scarcity hypothesis*, an effect of a price increase would be more deforestation in the short-run, but in a long-run the price increase may provide incentives to conserve the forests rather than to deplete them, therefore the net effect on deforestation would be negative (Rudel, 1998).[7] Since exports take place from one country to many countries, and also with different types of forest and agricultural products, it is difficult to specify one export price of these products for each country. Otherwise conversion of forestland to pasture is concentrated in Latin American countries than in African and Asian countries, where large-scale cattle ranching operations are driven for the purpose of meat export (Tole, 1998). Because of the emphasis given for the meat export, in addition to the forest products export, the export price index (EPI) is used as a proxy for the export prices for the Latin American countries. The EPI is a derivation based on prices for individual commodities (IMF, 2000).

For African and Asian countries, due to non-availability of data for the EPI for entire study period and for the countries included, an industrial roundwood price index (IRWPI) based on unit export value of industrial roundwood was calculated, because industrial roundwood consists most of the forest products exported from these countries (www.fao.org). First, the unit export value was found from the total value of export and the quantity of industrial roundwood products. Then the unit export values were converted into constant US$ for the year 1995 to find the index (IRWPI) for the same year as the base year.

(xi) Time Trend (Technological Change)

Time trend is used as a proxy for other exogenous time dependent variables such as technological progress in agriculture. Angelsen and Kaimowitz (1999) suggest that if a technological change in agriculture is labour- and/or capital- saving, it may free up more of these resources for additional farming and may clear more forestland. On the other hand, if the technological change is more labour- and/or capital- intensive, it may not likely to leave these resources for additional farming and may contribute to less deforestation. Therefore the sign of the coefficient of time trend is not predicted *a priori*.

4. ECONOMETRIC MODELS AND METHOD

For the empirical models, the depended variable (rate of deforestation), is defined as annual percentage change in forest area (DEF). The specification of all explanatory variables provides results that can be interpreted directly as regression coefficients, except quadratic term of the variable *GDP per capita* to validate the EKC hypothesis. Since the analysis of empirical models is a panel data method that involves cross-sectional and time series data, the country effects is specified by α_i and the time trend by TT. The coefficients of variables are given by β's and the error term is by $\varepsilon_{i\,t}$. Based on these criteria the empirical models are specified in the following way:

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

[7] Sometimes higher export prices can have an indeterminate effect on deforestation in the long-run, depending on the net effect 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.

The above model is estimated for Latin American countries. But for African and Asian countries the variable IRWPI is employed instead of the variable EPI in the same model, as discussed in Section 3. Panel data method facilitates identification of net impact of the underlying causes on deforestation. The standard deviations of the selected variables used in the cross-country comparisons are shown in Appendix 2. Multicollinearity is not a problem for the variables in the samples.[8] Simple pooled regression, fixed effects and random effects models were tested to estimate the parameter values of the model for each region.

For Latin America, preliminary investigation indicated that fixed effects model performed better than constant intercept model (i.e. simple pooled regression) by F-test. While random effects model performed better than constant intercept model by LM test. However the random effects model favored over the fixed effects model by Hausman test.[9] The constant intercept and the fixed effects models are homoscedastic and nonautocorrelated and estimated by Ordinary Least Squares (OLS) method. But the random effects model was estimated by flexible two step Generalized Least Squares (FGLS) method. The use of observations that are aggregations over varying number of countries is likely to give rise to heteroscedasticity problem in the estimation and render the OLS estimates of the constant intercept and the fixed effects models inefficient. Since the random effects model was favored from the respective statistical tests, whose estimated parameters are efficient because of the FGLS method, only the problem of autocorrelation (AR1) in the random effects model was considered. Presence of autocorrelation was deducted from Durbin-Watson statistics and this problem was eliminated by AR1 correction with Cochrane-Orcutt iterative procedure.

For Africa and Asia, preliminary investigation has shown that fixed effects models perform better than constant intercept and random effects models. However, the OLS estimates of the respective fixed effects models have been corrected for heteroscedasticity and autocorrelation. Following Breuch-Pagan test for heteroscedasticity, White correction (robust OLS covariance matricx) has been applied to eliminate heteroscedasticity. Following the Durbin-Watson statistics, Prais-Winston iterative procedure (full GLS transformation) has been applied to eliminate autocorrelation. The parameter estimates, after eliminating autocorrelation, are not found to vary from that of the initial ones for both regions. But the parameter estimates after eliminating heteroscedasticity are found to vary substantially from that of the initial ones for both regions. For this reason the parameter estimates of the fixed effects models that corrected for the heteroscedasticity are considered.[10]

[8] There was high collinearity between GDP per capita and its quadratic term as one would expect for polynomial regression. Otherwise, the correlation coefficient between AFA and GDP per capita is relatively high for Latin America, and the correlation coefficient between API and TT is relatively high for Africa and Asia.

[9] The procedures related to the different statistical tests are following Greene (1993).

[10] Asian sample consist relatively small number of cross sectional units than African sample for a large number of periods, and for this reason, equal error variances within the groups (i.e. group wise heteroscedasticity) was assumed for the Asian sample when correcting the problem of heteroscedasticity.

5. RESULTS AND DISCUSSION

Empirical results for the regions are summarized in Table 2. Discussion on the underlying causes of deforestation is followed by patterns of forest transitions (EKCs) for those regions.[11]

Table 2. Factors affecting annual deforestation rate of forests and woodlands, 1971-94[@]

Explanatory Variables	Latin America	Africa	Asia
AFA (FCGA)	0.345×10^{-5} ** (0.170×10^{-5})	0.261×10^{-3} *** (0.973×10^{-4})	-0.942×10^{-4} (0.830×10^{-4})
PFA (CAFP)	-4.239 *** (1.103)	-74.864 *** (23.087)	-6.777 (12.952)
API	0.213×10^{-1} *** (0.286×10^{-2})	-0.113×10^{-1} * (0.649×10^{-2})	-0.126×10^{-1} (0.201×10^{-1})
POPDEN	0.183×10^{-1} (0.332×10^{-1})	1.648 * (0.930)	-0.963 (1.565)
GDPPC	0.967 *** (0.301)	1.603 ** (0.637)	-3.568 * (1.857)
$GDPPC^2$	-0.326 *** (0.538×10^{-1})	-0.132×10^{-1} ** (0.542×10^{-1})	0.769 ** (0.374)
GDPG	-0.140×10^{-1} *** (0.424×10^{-2})	-0.719×10^{-2} (0.879×10^{-2})	0.936×10^{-1} *** (0.308×10^{-1})
DEBT	0.369×10^{-2} (0.324×10^{-2})	-0.780×10^{-2} (0.223×10^{-1})	0.434×10^{-1} (0.590×10^{-1})
EPI	-0.172×10^{-3} *** (0.370×10^{-4})	-	-
IRWPI	-	-0.360×10^{-4} (0.128×10^{-3})	-0.924×10^{-3} (0.865×10^{-3})
TT	-0.454×10^{-1}) *** (0.659×10^{-2})	-0.114×10^{-1}) (0.127×10^{-1})	-0.798×10^{-2} (0.417×10^{-1})
Constant[©]	0.299 (0.686)	24.25	10.864
EKC	Inverted U-shaped	Inverted U-Shaped	U-shaped
Turning point	US$ 1483	US$ 6072	US$ 2320

*** Statistically significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
[@] Standard errors are in parenthesis.
[©] Constant terms for the fixed effects models are average of the country effects.

A. The Underlying Causes of Deforestation

Since there is no a direct link between the underlying causes and deforestation, establishing a clear relationship between them is difficult one. Establishing such relationships

[11] The results discussed are based on the countries considered under each region (see Appendix 1) and that they should be interpreted cautiously when generalising these results for rest of the countries under each region.

also require good quality of data in particular for the deforestation estimates.[12] However, one should consider the results drawn from this study as more useful to *compare the directions* (signs) and *the relative magnitude of effects* (size of coefficients) of variables for the three regions.

(i) Absolute Forest Area (FCGA) and Proportion of Forest Area (CAFP)

Absolute forest area (FCGA) has positive effect on deforestation for Latin America and Africa, while negative effect for Asia (although not significant). In contrary, proportion of forest area (CAFP) has negative effect for Latin America and Africa, while positive effect for Asia (although not significant). These results imply that for Latin America and Africa the forest products export promotion policies are less likely to affect deforestation than the forestry sector and allied (non-forest sector) policies. Hence, appropriate policy instruments are needed in the forestry and allied sectors of these two regions and should be based on the specific needs of countries.

(ii) Agricultural Production and Technological Change

Agricultural production (API) has a positive effect on deforestation for Latin America, while negative effect for Africa. The positive effect implies cropland expansion into forest. Evidences suggest that in tropical Latin American countries landless peasants convert forest to grow crops for subsistence needs, while commercial farmers for export crops. Globalisation and economic liberalization increases global demand for agricultural and forest products than the demand faced at national and regional levels. This new prospects for exports may lead the people for rapid deforestation in countries where small domestic markets previously limited deforestation (Angelsen and Kaimowitz, 1999). This would be the case for certain Latin American countries like Brazil, Bolivia and Paraguay where forest has been cleared for soybean export (Contreras-Hermosilla, 2000).

The negative sign of time trend (TT) for all regions (although only significant for Latin America) indicates that technological progress in agriculture would reduce deforestation. The results imply that land intensifying technologies by increased application of labour, hybrid seeds, fertiliser and irrigation may be facilitated by agricultural research and extension policies to reduce the expansion of cropland into forests. But in reality these technologies are mostly accessible by commercial (big) farmers. Small farmers (peasants) often have very limited access to them and the complementary inputs they require (Bilsborrow and Geores, 1994). The question is then what policy incentives are taken to meet the requirements of the small farmers in these countries. Under the structural adjustment reforms and liberalization programmes, it is increasingly emphasised that subsidies for agricultural inputs such as fertiliser, chemicals and credit should be removed. In many countries the reforms have been a controversial issue with respect to their likely impacts on deforestation (Reed, 1996).

[12] The R^2 values of estimated models for Latin America, Africa and Asia are, respectively, 15.02, 25.11 and 20.25. The low R^2 values may be due to the quality of deforestation data which are defined based on the areas of forests and woodlands. However this is the only available data source for a cross-sectional time-series study.

(iii) Population Density

The positive effect of population density on deforestation for Africa suggests that population works through demand for roundwood consumption and agricultural land expansion (Kant and Redantz, 1997). In Africa, peasants and fuelwood collectors are the main agents of deforestation, particularly in dry areas of Sahal (Contreras-Hermosilla, 2000). Thus stronger policies for population control, off-farm employment opportunities to keep away the people clearing forests, re-/af-forestation programs to meet the growing demand for wood, secure land tenure policies and adequate means to increase the lands productivity for intensive farming systems are appropriate. The effect of population, on the other hand, can not be a cause by it self. The effect is endogenous at local and regional levels and decided by infrastructure availability, soil quality, distance to markets, off-farm employment opportunities, and other factors. Certain government policies such as road construction, colonisation, agricultural subsidies and tax incentives also influence migration of people into forests. The implications of such policies are that they are the actual causes of deforestation than the population growth per se (Angelsen and Kaimowitz, 1999).

(iv) GDP per Capita and GDP Growth

The effect of GDP per capita on deforestation is positive for Latin America and Africa, while negative for Asia. However, the effect of GDP growth on deforestation is negative for Latin America and Africa (although not significant for Africa), while positive for Asia. These results suggest that, particularly in a long run, GDP per capita and GDP growth would effect deforestation differently.[13]

The positive effect of GDP per capita implies, in particular for Africa, that nearly 70 percent of total energy requirement of the Sub-Sahara Africa is provided by wood. Fuelwood collectors are accounted for over 85 percent of wood removed from the forests and woodlands in this region. The negative effect of GDP per capita for Asia should not, however, be interpreted that wood consumption is not an active source of deforestation. The fact is that the role of fuelwood collectors is also significant in this region (Contreras-Hermosilla, 2000), although the Asian countries have implemented strong policies towards reforestation and regeneration of the deforested areas.[14] The positive effect of GDP growth for Asia implies that forest product export is a main cause of deforestation (Kant and Redantz, 1997). This could be partly explained by the generous timber concessions and low royalties that are common and favoured to encourage loggers in Southeast Asia (Angelsen and Culas, 1996).

(v) Debt (Debt as Percentage of GNP) and Export Prices (EPI and IRWPI)

The effect of debt on deforestation is as positive for all regions (although statistically not significant). Debt service consumes a larger share of income and foreign exchange earnings thereby squeezing out the investments needed for public programs including environmental protection that can reduce deforestation. Debt management in form of debt-for-nature swaps is increasingly being practiced by some countries as a mean to relieve debt burden and to conserve endangered tropical forests (Culas, 2006; Bhattarai and Hammig, 2001). The effect

[13] Usually one might expect that in a short- or medium- term the GDP per capita and the GDP growth would affect the deforestation in same direction.

[14] For example, country like India followed strong policies to reforest and to allow for regeneration of the deforested areas since 1950s.

of export prices on deforestation seemed to be negative for all regions (although it is only significant for Latin America). The negative effect implies that an export price increase would reduce deforestation and conserve the forests (most possibly in a long-run).

B. Patterns of Forest Transition (EKC)

An inverted U-shaped EKC empirically fits for Latin America and Africa, while a U-shaped EKC fits for Asia. The turning point for Africa (US$ 6072) is however much higher than the turning point for Latin America (US$ 1483). The turning point for Africa is also much higher than the current value of GDP per capita for many of the African countries in the sample. This implies that major damage to forest may occur in these countries well before this point is reached. However, for Asia, the turning point at US$ 2320 indicates that countries with income up to this level have a decreasing rate of deforestation. The U-shaped curve for Asia can also be interpreted that, even natural forest clearing is prevalent in this region, particularly for Southeast Asian countries, reforestation programs are greater in Asia than Latin America and Africa (Cropper and Griffiths, 1994; Bhattarai and Hammig, 2001).[15]

The inverted U-shaped EKCs for Latin America and Africa imply that current level of economic development in these regions is not appeared to deliver the forests from deforestation. Further, in addition to improving the current level of economic development, improving agricultural and forestry policies may play a greater role in delivering the forests from deforestation. Such policies should be targeted towards agricultural productivity, off-farm employment opportunity, land tenure and re-/af-forestation programs, and so on.

The main implication of results from this study, i.e. the patterns of forest transitions (inverted U-shaped EKC), is that some form of deforestation is inevitable during the early stage of development. However, the rate of deforestation could be minimized at the later stage of development with the incentives that are provided by the development itself, given that the development process should not exceed the ecological threshold (irreversibility) limits of the forests. The international REDD policy and its financial transfers can in fact provide such incentives for the required development.

Although the EKC studies across the geographical areas/countries could provide directions for implementing the REDD policy, case specific factors might influence the deforestation in different countries and socio-geographic zone. Therefore future research on this area would be focused on more disaggregated and local level studies (Scrieciu, 2007).

6. Conclusion and Policy Implications

This study establishes relationship between underlying causes and deforestation across Latin American, African and Asian countries using cross-sectional and time-series data. Employing an econometric model for forest transition (EKC) hypothesis, conditional on main underlying causes of deforestation, the study provides results and directions for implementing policies and instruments that can bring down the rate of deforestation.

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[15] According to the FAO estimates for 1990, the natural forest area in Asia decreased by 3.9 million hectare, but nearly 2.1 million hectares were planted , and that the net decrease in the forest and woodland area is by 1.8 million hectares (Cropper and Griffiths, 1994).

Evidences show that export promotion policies for forest products are less likely to influence deforestation than forestry and allied sector policies. Therefore, the forest and the allied sector policies need to be strengthened for Latin American and African countries. Population density affects deforestation positively for African countries and that reforestation programs to meet the demand for fuelwood and also off-farm employment opportunities, secure land tenure rights and population control measures could minimize the effect. Agricultural production influences deforestation positively for Latin American countries, implying that technologies progress for intensive and profitable farming systems could minimize the effect.

An inverted U-shaped EKC fits for Latin America and Africa but a U-shaped EKC for Asia. The higher turning point for Africa (than Latin America) suggests that major damage to forest may occur in some African countries well before the turning point is reached. The EKC for Asia however implies that even natural forest clearing is prevalent in this region reforestation is greater in Asia.

The inverted U-shaped EKC for Latin American and African countries implies that some form of deforestation is inevitable during the early stage of development. However, the rate of deforestation could be minimized at the later stage of development with the incentives that are provided by the development itself, given that the development process should not exceed the ecological threshold (irreversibility) limits of the forests. The international REDD policy and its financial transfers can in fact provide such incentives for the required development.

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APPENDIX

Appendix 1. List of countries used in the analysis (with years of data availability)

Africa	Asia	Latin America
Angola (85-94)	Bangladesh (92-94)	Bolivia (84-94)
Benin (91-94)	Cambodia (87-94)	Brazil (71-94)
Cameroon (71-94)	India (71-94)	Colombia (71-94)
Central African Republic (71-94)	Indonesia (71-94)	Dominican Republic (71-94)
Democratic Republic of Congo(71-94)	Malaysia (71-94)	Ecuador (71-94)
Congo Republic (71-94)	Papua-New Guinea (71-94)	Guyana (71-94)
Cote d'Ivore (71-94)	Philippines (71-94)	Honduras (75-94)
Equatorial Guinea (85-94)	Solomon Island (78-94)	Jamaica (71-94)
Gabon (71-94)	Sri Lanka (71-80; 90-94)	Peru (71-94)
Ghana (71-94)	Thailand (71-82; 90-94)	
Guinea (86-94)	Viet Nam (85-94)	
Kenya (78-84; 90-94)		
Madagascar (71-94)		
Malawi (71-79;90-94)		
Mozambique (81-93)		
Nigeria (71-94)		
Rwanda (91-94)		
Senegal (93-94)		
Sierra Leone (92-94)		
Tanzania (89-94)		
Togo (90-94)		
Zambia (90-92)		
Zimbabwe (76-94)		

Appendix 2. Descriptive statistics of variables in the study, by region, 1971-94

Variable	**Latin America**	**Africa**	**Asia**
Deforestation rate (annual %)			
Mean	0.19	0.17	0.33
SD	0.80	1.18	1.93
Total forest area (1000 ha)			
Mean	90726.22	29635.96	35813.48
SD	172098.88	41677.81	36578.66
Proportion of forest area			
Mean	0.51	0.47	0.55
SD	0.23	0.22	0.25
Population density (people per			
ha)	2.82	0.30	1.25
Mean	4.47	0.34	1.31
SD			
Agricultural production index			
Mean	91.75	87.30	85.73
SD	20.64	16.32	19.10
GDP per capita (US$1,000s)			
Mean	1.72	0.80	0.94
SD	0.99	1.24	0.78
GDP growth rate (annual %)			
Mean	3.28	2.21	5.26
SD	5.01	7.56	4.36
Debt (percentage of GNP)			
Mean	9.28	5.63	5.43
SD	10.05	4.99	4.18
Export price index			
Mean	188.01	-	-
SD	600.91	-	-
Industrial roundwood price index			
Mean	-	136.13	221.02
SD	-	236.42	290.91
Number of countries	9	23	11
Number of observations	199	330	190