

**ADDIS ABABA UNIVERSITY**  
**SCHOOL OF GRADUATE STUDIES**

**GOVERNANCE, CORRUPTION AND ENVIRONMENTAL**  
**KUZNET'S CURVE FOR DEFORESTATION IN**  
**THE SUB-SAHARAN AFRICA**

By

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**“Governance, Corruption and Environmental  
Kuznet’s Curve for Deforestation in the Sub-  
Saharan Africa.”**

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## *Abstract*

Environmental Kuznet's Curve hypothesis an argument stating that development has an inverted 'U' shaped relationship with environmental quality. At early stages of development the damage to the environment is higher but as development proceeds and as people reach a certain threshold level of per capita income more concern will be given to improvement of environmental quality. The main aim of such kind of studies is to find a development path where less damage to the environment is done. This study tries to look the presence of EKC relationship for deforestation. Further the study tries to analyze the role institutional setups in the EKC relationship form 1995 to 2005 in the Sub-Saharan Africa. In the study the researcher has used 33 countries as a sample. The researcher used the panel data analysis because of its advantage of incorporating both time series and cross sectional dimensions. The study has found that EKC hypothesis holds for deforestation in the region. Turning point with per capita income which is higher than the current level of most of the countries in the region implying that more damage is going to happen to the resource before improvement comes. Moreover, the study has found that governance plays an important role in deforestation process having a negative relationship with it. The study results imply that good governance may result in a turning point which can result in less damage to the environment.

## *Chapter One*

### *Introduction*

#### *1.1 Background of the Study*

The Sub Saharan Africa (SSA), according to the World Development Indicator (WDI) (2008), with surface area of 24, 267 (1,000 square kilometers) and 765 million inhabitants in 49 countries and with population density of 33.2 people per square kilometer, is one of the least economically developed areas of the world. The region accounts for 11% of the world population and it has a population growth rate of 2.5% per year. The composition of the population in 2005 implies that 53% of the population is with in the working age (i.e. between 15 years and 64 years).

Economically the region is least of the rest of the world. It takes only 1.5% of the world's Gross Domestic Product (GDP). Further the per capita income of \$560.68 is very much lower than the world average of \$5643.69 (WDI, 2008). But the average annual GDP growth rate of 5.9% is way more than the world's 3.5%.

In 2005, 27% of the land in the region is under forest cover. According to the World Bank (2004), the rate of deforestation for the period 2001 is 0.8%. This rate of deforestation is higher than the world's average rate of deforestation of 0.22% reported in FAO's Forest Resource Assessment (FRA) (2006).

## ***1.2 Statement of the Problem***

Deforestation is one of major environmental problems which is attracting the attention of scholars. Forests are sources of timber, biodiversity, control soil erosion and are store of carbon. Forests have different economic and social value. Moreover forests have influence on climate sustainability. Many studies have shown that deforestation in the developing countries has led to environmental degradation like expanding desertification, erosion of agricultural lands, drying up water bodies during dry season, disappearance of plant and animal species, change of both regional and local climate change (Dasgupta, 1989; Hoiser, 1998; Ehui and Hertel; 1989). Studies focusing on the factors driving deforestation have great deal of interest because of their implication on policy makers. Letiao (2006) took the example of studies of environmental degradation and economic growth:

*“Given the current debate on global warming, air quality and other serious environmental problems, a better understanding of the relationship between economic growth and the environment is of great interest to policy making.”*

The Environmental Kuznet’s Curve (EKC) hypothesis is an instrument to discuss the relation between economic development and environmental degradation. The main synthesis behind this hypothesis is that at the early stage of development environmental degradation will be high. But as development reaches to some stationary level it will create incentive to environmental improvement (Shafik, 1994; Bhattarai and Hamming, 2002 and Barbier, 1997). The hypothesis states that there is an inverted ‘U’ shaped relationship between environmental degradation and economic development. The main aim of EKC studies is to find a development path where minimum damage is done to the environment.

Perman et al.(2003) further described the EKC relationship as:

*“If the EKC hypothesis held generally, it would imply that instead of being a threat to the environment as it is often argued, economic growth is the means to environmental improvement. That is a countries develop economically, moving from lower to higher levels of per capita income, overall levels of environmental degradation will eventually fall.”*

In addition to the above arguments about the EKC relationship between environmental degradation, the hypothesis still is not proved for many environmental quality measures. Shafik (1994) found out that it is possible to grow out of some environmental problems, but not from all environmental quality degradations. According to Barbier (1997),

*“EKC relationship is a falsifiable hypothesis that can and will continue to be tested by a variety of empirical investigation.”*

In developing countries like the Sub-Saharan Africa (SSA) forests are under the public control. Thus the EKC relationship between economic development and deforestation can be affected by different institutional, structural and governance variables. Perman et al. (2003) explained that empirical status of EKC relationship has great importance. If there is an EKC relationship, it shows that economic growth is good for the environment so that there is no need to hold back economic growth to protect the environment.

There is still a gap on the EKC relationship for deforestation. There is a lot to be done on this respect. More over the impact of institutional setups on EKC is not also very clear. Thus this study will contribute to the knowledge gap in the applicability of EKC for deforestation and the importance of institutional factors on this relationship by taking the SSA. The importance of institutional setup can be viewed through its impact on the turning point of EKC curve. A good institutional setup may result in turning point of the EKC before more damage is done to the environment.

The SSA is a region of surface area 24, 267, 000 sq. km. From this total surface area around 25% is under forest cover (World Bank, 2004). According to World Bank (2004), the annual average annual rate of deforestation for the region was 0.8% for the time 1990 – 2000. For the same period the world's average annual rate of deforestation was 0.22% (Food and Agricultural Organization of United Nations (FAO), (2006)). This shows that for the year stated above annual rate of deforestation for the regions is greater than the rate for the whole world.

Countries in the SSA have been pursuing different economic policies to attain the Millennium Development Goals. This study will try to see the impact of these measures taken with in the Frame work of the EKC framework for the time 1995 to 2005. More over, the study will also try to examine if institutional factors have influenced the EKC relationship.

This study will try to answer the following questions:

- Is EKC relationship for deforestation valid in the SSA?

- What is the importance of institutional factors like governance and corruption for the EKC relationship?

### ***1.3 Objectives of the Study***

#### **1.3.1 Major Objective**

The major objective of this study is to inspect if EKC relationship for deforestation is valid in the SSA.

#### **1.3.2 Specific Objectives**

The specific objectives of the study are:

- To see the impact of Governance on the EKC relationship for deforestation.
- To see the importance of Corruption for the EKC relationship of deforestation.
- Analyze the effect of some selected policy variables and structural factors on deforestation.
- Draw some policy implications.

### ***1.4 Justification of the Study.***

This study will have many important implications. As governments in the SSA are try to attain a faster economic growth using different policy measures, it might have an implication on deforestation. In addition to the above, the results of the study will help government to understand how their governance and corruption contributes to the deforestation process in the region. The results of this study will give policy makers the implications of their measures on the forests of their nations. The results of the study will be also helpful for environmental



agencies in the SSA. It will give picture of impact of economic development in the region on the environment (forest). The study can be used as a benchmark for other studies to be done on this subject in the region.

### ***1.5 Scope of the study***

This study focuses on only the EKC relationship for deforestation and the implication of governance and corruption on this relationship. The study will not focus on primary or underlying causes of deforestation. This study will be also done on macro level not on micro level.

### ***1.6 Limitations of the Study***

Scarcity of relevant data is major problem faced in this study. Due to lack of data the researcher focuses on only 33 countries in the region out of 49. Moreover the lack of data has limited the scope of the study from 1995 to 2005.

## *Chapter 2*

### *Literature Review*

#### *2.1 Definition of Deforestation*

The definition used for deforestation used can have an impact on results of a study.

FAO(2005) defines forests as:

*“Land spanning more than 0.5 hectares with trees more than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these threshold in situ.”*

This definition does not include land under agriculture or land under use. Pagiola (2005) stated that plantations and other managed forests may or may not be included in the definition of forest.

Many studies have adopted FAO’s definition of deforestation (Kaimowitz and Angelsen, 1998). This definition states that deforestation is clearing of forest land for all forms of agricultural uses, and other land uses such as settlements, infrastructure and mining. Hoiser (1988) defines deforestation as: “Movement to a lower level of tree canopy cover. This decline may include clear felling or economic actors harvesting trees more rapidly than they can grow.”

Pagiola (2005) took another direction to define deforestation. He describes deforestation as a complete loss of forest cover. Further he explains that deforestation can be viewed as decline

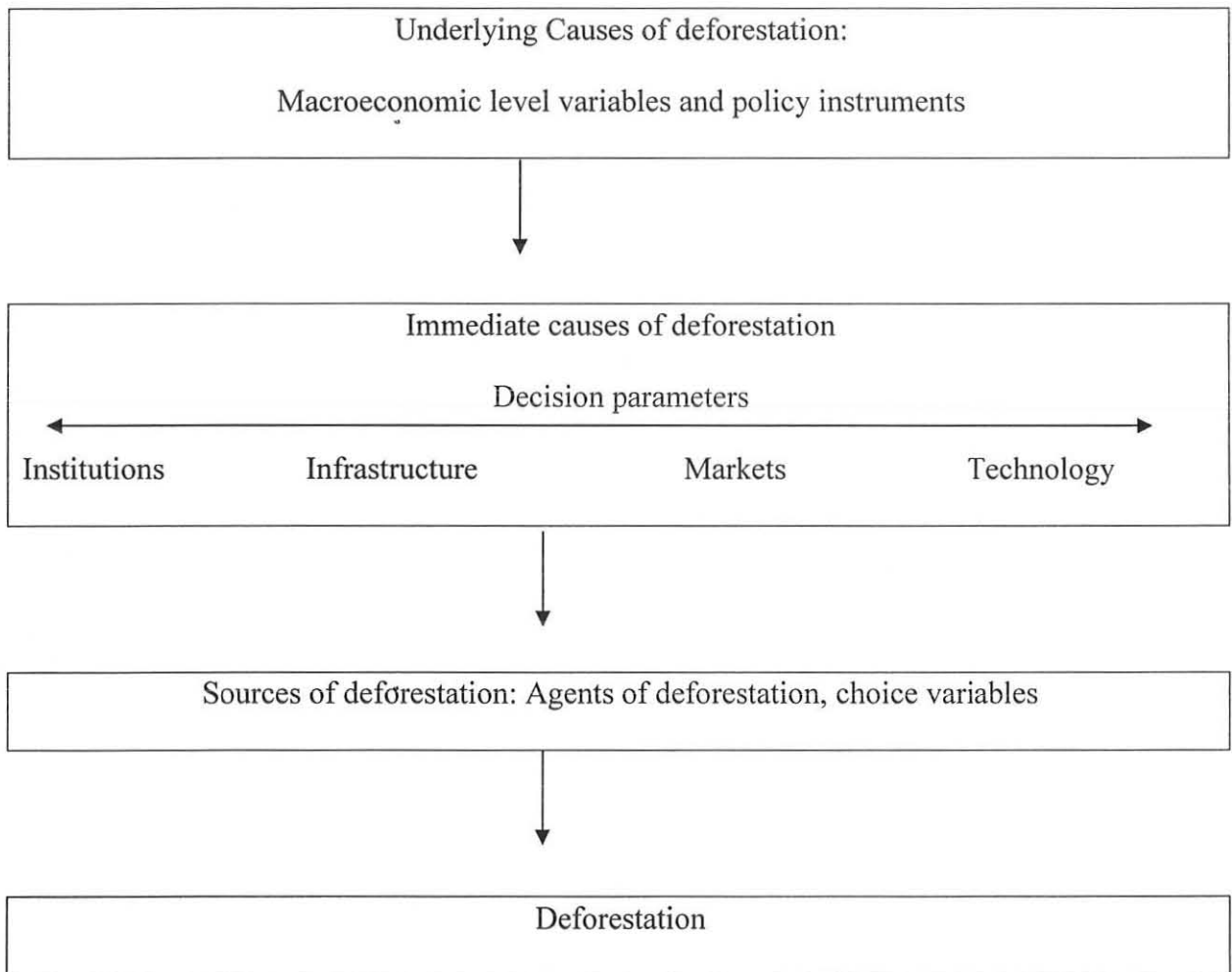
of forest below a given (but varying between nations) proportion of land cover and loss of primary forest alone. He also stated that narrow definition of deforestation is clear cutting an area of natural forest. If the logged area is regenerated as secondary forest or was replanted as a forest plantation this narrow definition will be taken as broad definition. Grainger (1999) defines it as the clearance of forest for agriculture or other purposes. While Yeridoe and Nanang (2001), define deforestation as average annual decline in forest and wood land area. Some studies have adopted the definition of decline in forest area (Cular and Dutta, 2002; Shafik, 1994)

Pagiola (2001) has taken further insight to the implication of definitions of deforestation. Definitions of deforestation focusing on loss of forest cover will assign bigger share of role of deforestation to logging. Definitions of deforestation that focus on loss of tree cover will give the larger share of the blame of deforestation to small holder agriculture.

This study uses FAO's definition of deforestation, annual decline in forest area. This definition is adopted because it includes factors which are important (agriculture, clearing land for other purposes like mining and infrastructure). More over this definition is assumed to be a broad definition (Pagiola, 2005)

## ***2.2 Causes of Deforestation***

Angelsen and Kaimowitz (1998) have reviewed more than 140 studies on deforestation. In their review they have found that five types of variables are used in models of deforestation: Magnitude and location of deforestation (main dependent variable), agents of deforestation (individuals, households, companies), the choice variables (factors influencing agents decision but are external to them), macroeconomic variables and policy instruments (variables affecting forest clearing indirectly through their influence on the decision parameter). They build a framework of deforestation models which is presented in the following diagram:



*Figure 2.1: Theoretical Framework of Models of Deforestation (Adopted from Angelsen and Kaimowitz, 1999)*

In this review of 140 models they have classified models using two criteria. The first criterion used is scale of the studies. In this category there are three models of deforestation:

- Household and firm or microeconomic level
- Regional level and
- National or macroeconomic level.

The second criterion used is methodology of the studies:

- Analytical: These are abstract and theoretical constructs
- Simulation models: use parameters based on stylized facts drawn from various sources to assess scenarios
- Empirical models: quantity relations between variables based on empirical data i.e. regression analysis.

Their review shows that most models of deforestation are based on regression analysis.

Following Kaimowitz and Angelsen (1998), who have reviewed 150 studies on deforestation, one can categorize factors affecting deforestation into three.

- Direct sources of deforestation
- Immediate causes of deforestation
- Underlying causes of deforestation

This section will present the causes included in these three categories.

2.2.1 ***Direct Sources of deforestation:*** These factors are mainly includes expansion of crops and pasture. Geist and Lambin (2001), discussed that these factors are human activities that directly affect environment. According to them these factors are commonly categorized in three groups.

a. ***Expansion of Land and Pasture (Agricultural Expansion):*** These causes include burning of clearing land for cultivation and destruction of plantable plants by livestock (Mikesel, 1960). Dauvergne (1993) put forward four explanations to causes of deforestation. Two of these explanations, Tropical Government explanation and Development explanation, put expansion of land and pasture as a major cause of deforestation. Geist and Lambin (2001) argued expansion of cropped land and pasture is clearly most important cause of deforestation. Ehui and Hentel (1989) explained greatest reason for forest destruction in tropics is increasing pressure from agriculture which is fueled by population growth. According to Barbier (1993), it is axiomatic to state that major cause of tropical deforestation is the conversion of forest to agricultural land. Yiridoe and Nanang (2001) studied the causes of deforestation in Ghana and found that food crop production has contributed to the process of deforestation.

b. ***Harvesting or Extraction of Wood (Wood Extraction):*** These factors are heavily affected by underlying factors. Development explanation and environmental explanation stated in Dauvergne (1993) argue that commercial logging and fuel wood extraction are major causes of deforestation. This argument of the two explanations is also shared by Mikesel (1960). Yiridoe and Nanang (2001) found forest products

export and fuel wood consumption are factors aggravating deforestation process in Ghana.

- c. ***Expansion of infrastructure:*** This factor includes building roads and other infrastructures. Barbier et al. (1997) discussed that road building in frontier forest areas make forest lands artificially cheap and readily available for farmers.

2.2.2 ***Immediate causes of deforestation:*** According to Angelsen and Kaimowitz (1998), factors categorized as immediate causes are agricultural input prices, agricultural output prices, off farm wages and employment, credit availability, technological progress (direct effect), homesteading property regime, land tenure security and timber prices. Higher prices makes frontier agriculture profitable this will lead to shifting of resources in to forest clearing both by existing population and by migrants from other areas. Higher prices for agriculture products stimulate forest clearing (Kaimowitz and Angelsen, 1998).

2.2.3 ***Underlying Causes of Deforestation:*** broader economic, political, technological cultural and demographic factors and fundamental social pressures that underpin the proximate factors of deforestation. Factors included in this category are: Economic factors, policy and institutional factors, technological factors, cultural factors (attitudes and lack of public concern for forest conservation and willingness to continue holistic forest practices such as burning), demographic factors (Myers, 2007; Geist and Lambin, 2001)

**2.2.3.1 Demographic factors:** Population increase may aggravate deforestation. Growing population needs more land for food, fuel wood, timber or other forest products (Angelsen and Kaimowitz (1999). According to Martinez (2008), these arguments are rooted in Malthusian perspective that expanding populations eat up gain from agricultural productivity (efficiency) so the population will be required to clear additional land. Lambin et al. (2001) population and poverty drive deforestation mostly through shifting cultivation.

Some studies found out that increase in population growth aggravates deforestation (Martinez, 1998; Deacon, 1994; Bhattari and Hamming, 2002). While Angelsen and Kaimowitz (1999), in their review of studies on deforestation, found that there is weak support for the explanation that population growth is a driving force of deforestation. Cular and Dutta (2002) found a positive relationship between population density and deforestation for Africa.

Geist and Lambin (2001), using Meta – analysis to identify factors leading to deforestation, found weak explanatory power to population. While Shandra et al. (2008) studied causes of deforestation on 68 poor countries. They found that population growth does not drive deforestation.

Other studies tried to look into the relationship of population growth and deforestation by focusing on rural or urban population growth. The results are conflicting. Bhattarai and Hamming (2002) found negative relationship between rural population density and deforestation. While Shandra et al. (2008) found positive relationship between these two variables.

**2.2.3.2 Economic Growth:** As the economy grows it provides more incentive to environmental protection programs leading to environmental improvement (Angelsen and Kaimowitz, 1998).

Martinez (1998) also discussed the modernization perspective, which argues environmental degradation is result of the level and rate of development with in a given country. This theory, according to her, uses growth, technology, urbanization, transportation, education, and industrialization as indicators of development.

Empirically the relationship of economic growth and deforestation is not a clear. Deacon (1994) has found that there is a negative relationship between economic growth and deforestation. Shandra et al. (2008) found a positive relationship between economic growth and deforestation, while Bhattarai and Hamming (2002) found negative relationship between the two variables. The study done by Cular and Dutta (2002) shows that different results can be derived for different regions.

**2.2.3.3 Economic Policies:** Barbier (1993) argued that economic policies aimed specifically at forestry sector, including domestic and trade instruments lead to forest exploitation. He explained that real currency devaluations provide incentives to increase domestic production of export items including timber productions. This is because this will lead to increase in competitiveness of domestic output in the international market. This argument can be further explains that macroeconomic policies (fiscal and monetary policy) can contribute to deforestation. These macroeconomic policies like exchange real exchange rate devaluation and level of debt servicing ratios can have impact on timber trade and deforestation. Amsberg

(1998) underlined that devaluation of the national currency increases the profitability of agriculture. Devaluation contributes to increases conversion of unmanaged forests.

Angelsen and Kaimowitz (1999) argued that policies designed to increase agricultural and forest product exports are likely to affect deforestation more than policies that promote production for the domestic market.

Dauvergne (1993) discussed the effect of economic policies with the help of “Public Policy” explanation of deforestation. This explanation emphasizes on destructive impact of tropical government policies developed by various bureaucratic departments. This explanation argues that government policies destruct the tribal people ‘land use right’, this in turn results in unstable and destructive farming systems.

**2.2.3.4 Debt and Structural Adjustment Programs:** Gullison and Lossos (1993) explained that debt reduction could be linked to reform of sectoral policies concerning natural resources used. Moreover, debt induced economic problems caused increased poverty, which forces people to use and degrade marginal lands such as tropical forests. They further put forward that debt induced shortages will prevent the initiation and financing of environmental programs. According to Barbier (1993), increasing pressure to meet debt servicing payments may also contribute to deforestation if countries follow short-term policies at the expense of long term sustainable development.

Yiridoe and Nanang (2001) discussed that macroeconomic variables such as a change in external debt and change in income per capita affect deforestation by working through the first products exported, small scale industry and domestic fuel wood energy needs.

Angelsen and Kaimowitz (1999) explained the impact of trade liberalization and structural adjustment as:

*“Structural adjustment and trade liberalization policies designed to increase the terms of trade in favor of agriculture may have short term or medium term recessionary consequence that reduce urban food demand, which should lead to lower rather than higher agricultural prices and thus to less deforestation.”*

Debt burden of a nation is empirically found out to have conflicting impact on deforestation. Shandra et. al (2008) found debt and structural adjustment increases deforestation, while Martinez et. al (2002) found that impact of debt is insignificant. This insignificance of debt is also found in Bhattarai and Hamming (2002). Culas(2004) has studied the cause of deforestation on 52 tropical countries and found positive relationship between deforestation and debt level of a nation. But Gullison and Lossor (1993) argued that the effect of debt is overstated. According to their argument the effect of debt has been given a high stress while it has small impact.

Factors other than underlying and approximate causes are referred as predisposing conditions (Myers, 2007; Geist and Lambin, 2001). This includes land characteristics, features of biophysical environment that will make the area easy to access. Areas will have suitable

topography for agriculture and have high soil quality making the land susceptible to deforestation process.

### 2.3 Models of Deforestation

Barbier (2001) categorized cross national models in to four.

- a. **EKC analysis:** This analysis explains that environmental bad first increased eventually falls as the per capita income of a country rises. Horbach (2002) describes that and environmental EKC describes a time path characterized initially by a positive correlation between pollutants and GDP becoming negative during later phase of economic development of the country. Azomahou et al. (2005) EKC implies that starting from low levels of income per capita, environmental degradation increases, but after a certain level of income (turning point) it diminishes.

$$F_{it} - F_{it-1} = f(Y_{it}, Y_{it}^2; Z_{it}) \dots \dots \dots \dots \dots \dots \dots \dots (2.1)$$

Where  $F_{it} - F_{it-1}$  = measure of deforestation

$Y_{it}$  = per capita income

$Z_{it}$  = other explanatory variables

There are many competing explanations to the theoretical background of EKC models. Barbier (1997) explained that EKC maintains that there is an inverted ‘U’ shaped relationship between a variety of indicators of environmental degradation and level of per capita income. Martinez et al. (2002) argues that EKC for deforestation is rooted in structural and political modernization. Their argument focuses on dynamics associated with urbanization, the growth of service sector activities and strong democratic states. Bhattarai and Hamming (2002)

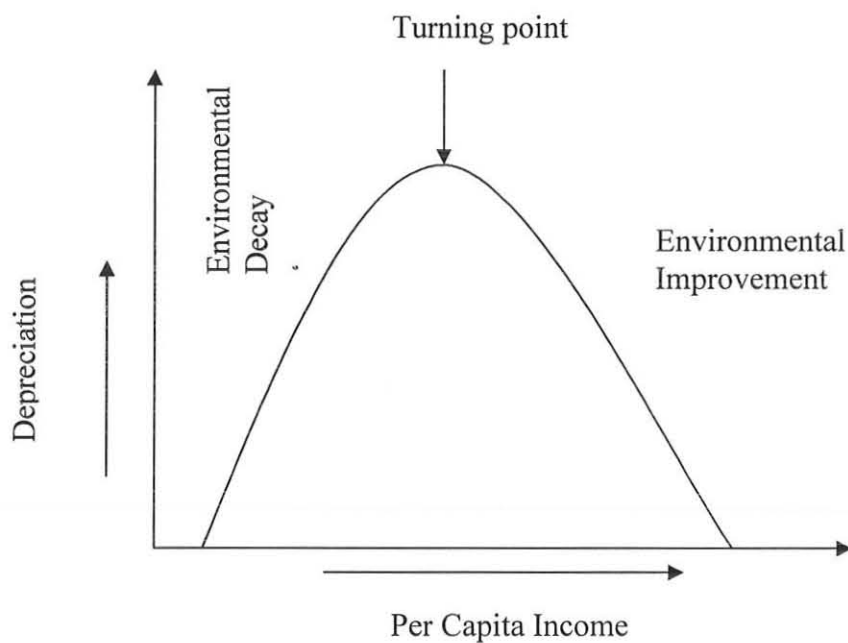
highlighted EKC assumes that low income countries clear forest area with out replacement or at least that replacement rate is less than the harvest rate.

Gergel et al. (2004) describes environmental EKC as:

*“EKC postulates that environmental quality is initially degraded with increasing economic prosperity, until reaching some turning point where environmental quality improves with increase in wealth.”*

Chambers (2008) explained EKC as: In the initial stage of economic development unregulated economic activity damages the environment. As income grows, the public demand foe environmental quality rises and more public policy is focused on environmental protection.

Graphically EKC is presented as:



**Figure 2.2: Typical EKC Diagram (Yandle et al. ,2004)**

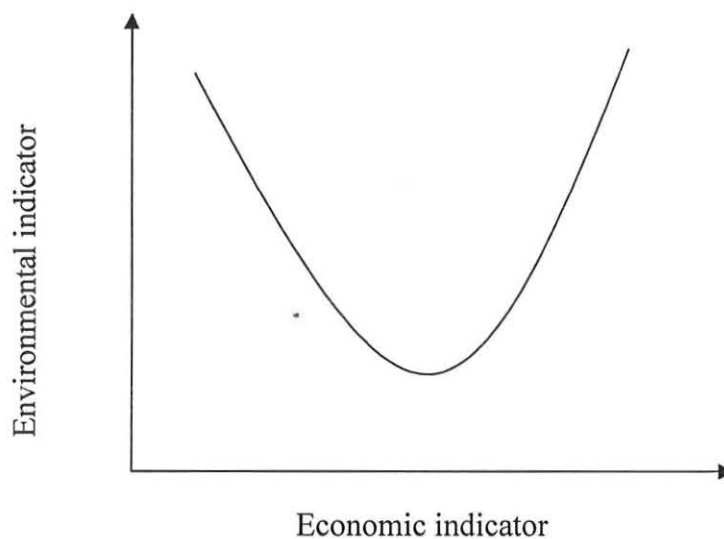
Yandle et al. (2004) argues that at lower levels of per capita income found in pre industrial and agrarian economies where most economic activity is subsistence farming pristine environmental conditions are expected. They further explained that:

*“EKC relationships suggest that as development increases due to greater use of natural resources, more emissions of pollutants, the operation of less efficient and relatively dirty technologies, the high priority given to increase in material output and disregard for or ignorance of the environment consequences of growth. However, as economic growth continues and life expectancy increases, cleaner water, improved air quality and generally*

*cleaner habitat become more valuable as people make valuable as people make choices at the margin about how to spend their incomes.”*

Perings and Ansuategi (2000) stated the turning point as a point defining the levels of per capita income at which emissions start to fall as income rises further.

Unlike the conventional ‘inverted U shaped’ hypothesis of EKC, Gergel et al. (2004) provided a U shaped curve for EKC as:



***Figure 2.3: EKC Curve (Gergel et al., 2004)***

They explained that high environmental quality exists in areas with little economic development and is initially degraded with increasing economic development. Once economic development proceeds past some critical turning point, environmental quality will improve. Once societies pass some threshold level of wealth that allows them to “purchase”

environmental quality through various means the environmental degradation will decrease resulting in improvement of the environment.

Empirical findings of EKC hypothesis vary based on the sample and place considered. Barbier (2001) found that EKC hypothesis works for Asia but it is rejected for other regions. But in the same study, inclusion of institutional factors in the model resulted in acceptance of EKC for all regions in the study. Bhattarai and Hamming (2002) proved that inverted ‘U’ shaped EKC is empirically found to fit to Latin America and Africa. Shafik (1994) found per capita income has little bearing on the rate of deforestation. Perings and Ansuategi (2000) found no evidence for EKC in deforestation in their study.

- b. Competing land use models:** These models assume that forest loss in tropical countries is competing land use. Specifically between agriculture and forests.

$$F_{it} - F_{it-1} = A^D(V_{it}; Z_{it}), \frac{\partial A^D}{\partial V_{it}} < 0 \quad \dots \dots \dots \quad \dots (2.2)$$

Where  $V_{it}$  = Opportunity cost or price of agricultural conversions

$A^D$  = the demand for converting forest land to agriculture



- c. Forest land conversion Models:** These models assume that households use their available labor either to convert their own land or purchase it from a market.

$$A_{it}^D = A^D(P_{it}, W_{Lit}, W_{it}; X_{it}, Z_{it}), \frac{\partial A^D}{\partial P_{it}} > 0, \frac{\partial A^D}{\partial W_{Lit}} < 0, \frac{\partial A^D}{\partial X_{it}} > 0 \dots \dots \dots (2.3)$$

Where P = The price of agricultural output

$W_L$  = rural wage

W = Vector of other inputs

X = Factors influencing the accessibility of forest areas (e.g. roads)

- d. Institutional models:** Uses variables like: Land use conflict, security of ownership (property right), political stability and 'rule of law'.

$$F_{it} - F_{it-1} = f(Q_{it}; Z_{it}) \quad \dots \quad \dots \quad \dots \quad \dots \quad (2.4)$$

Where  $Q_{it}$  = Institutional factors

Barbier (1993) explained that institutional and legal arrangements governing land tenure and transactions have played an important role in deforestation. He took the example of formal property law and titling regulations in developing countries. In developing countries, such institutional setups ensure that land clearing is the only means of securing claims to frontier forest land holdings. Barbier (1997) stated that insecure property rights on frontier forest areas make forest lands artificially cheap and readily available for farmers. Yandle et al. (2004) argues that more secure property rights over resources will cause the race to the bottom to end sooner, and environmental improvements to come about at lower cost.

Li and Reuveny (2006) explained that democracy can have positive and negative impact on environment. The positive impact is through freedom of information to interested groups, more responsiveness to environmental needs of the public, more likely to comply with

environmental agreements because they respect rule of law. The negative effect is through unchecked natural resources exploitation and environmental mismanagement by self – interested individual group.

Letiao (2006) has stated corruption can contribute to environmental degradation by taking forests as example. This argument explained that corruptions in the forest include:

- Political parties granting harvesting concessions in return for payments from logging interests
- Falsifying harvesting records to exclude protected species
- Underreporting harvesting volumes or facilitating illegal transporting of timber.

Many studies have proved the importance of governance and institutional factors in deforestation process. Deacon (1994) using institutional models discussed in Barbier (2001) found out that when government lacks ability to enforce controls on how government forests are used they tend be to retreated as free access. Nelson et al. (2001), using spatial econometric techniques to estimate socio economic and geophysical variable on the choice of land, found that a significant loss of forest cover would result if effective property rights were removed. Wand et al. (2007) using 4-Quadrant approach proved that control of corruption increases forest cover. Bhattarai and Hamming (2002) stated quality of governance is a critical determinant of tropical deforestation with a negative coefficient for governance.

According to Zaimeche (1994), in his study o Algeria, inappropriate government policies, fast rising pressure on forest lands and administrative inefficiency led to wide spread deforestation.

Li and Reuveny (2006) studied the impact of democracy on five aspects of human induced environmental degradations: Carbon dioxide emissions, nitrogen dioxide emissions, deforestation, land degradation and organic pollution in water. They found out that democracy reduces all five types of environmental degradation.

## *Chapter Three*

### *Methodology*

#### *3.1 Data*

This study uses secondary data for the year 1995 - 2005. The data for the main dependent variable, deforestation, is collected from FAO forest resource assessment 2005. Data for macroeconomic and structural variables is collected from World Bank Development Indicators (WDI) which is rich in such kinds of data for developing countries like SSA.

##### **3.1.1 Dependent Variable (Deforestation)**

Deforestation in this study is measured as annual decline in forest area. The data for this variable is collected from the FAO's Forest Resource Assessment 2005. FAO (2005) stated the resource assessment in 2000 has improved the previous assessments by including more countries and one single definition for global forest. Further the assessment has improved in using more technological ways of measurements like remote sensing.

#### *3.2.2 Independent Variables*

##### **i. GDP Per capita ( $Y_{it}$ )**

This variable is included in the model to capture the EKC hypothesis. In order to analyze this relationship it is included in quadratic form. The data is collected from WDI (2008) CD-ROM. The variable is expected to have positive sign for the linear variable and negative sign for the squared variable which implies an inverted U shaped relationship. This inverted 'U'

shaped relationship implies that at the initial stage of development the environment will be degraded but after a certain stage the economic development will provide incentive leading to environmental improvement (Bhattarai and Hamming (2002)

**ii. Economic Growth ( $g_{it}$ )**

This variable measures the annual growth in the GDP of nations. This variable is expected to have a negative variable. This refers that as the economy grows it provides more incentive to environmental protection programs leading to environmental improvement.

**iii. Agricultural Land Expansion ( $Ale_{it}$ )**

Agricultural land expansion can be done by moving towards frontier forest lands. Barbier et al. (1997) put forward that in many developing countries the main problem of deforestation is agricultural expansion. The data for this variable is obtained from the WDI 2008, taking a proxy of percentage of land used for agriculture. This variable is expected to have a positive sign.

**iv. Population growth ( $pop_{it}$ )**

The population puts pressure on the forest from its increasing demand of food, fuel wood and timber products (Angelsen and Kaimowitz, 1999). The variable is expected to have a positive sign, referring that higher population growth leads to higher deforestation.

**v. Rural Population density ( $rpop_{it}$ )**

As we have stated for the above variable, rural population density will put a pressure on the forest area come from increasing demand for food and agricultural land. This variable is also expected to have a positive sign.

**vi. Government Debt Level ( $Dt_{it}$ )**

Foreign debt encouraged and financed by international corporations is considered to be the most important economic variable driving destructive forest practices. According to Gullison and Lossos (1993), highly indebted nations increase exploitation of forests to earn foreign exchange for debt payments. The variable is expected to have positive sign.

**vii. Trade intensity ( $Oppen$ )**

The trade openness of a nation show how much country is participating in the international trade. The more open a country is to the international world, more export promotion policies will be conducted leading to more pressure on the forest lands. This variable is expected to have a positive sign.

**viii. Initial Forest Stock ( $F_{it}$ )**

This variable is used in this study to control the effect of forest size on deforestation. Countries with large forests have greater potential for deforestation in than countries with small area of forest cover because of accessibility. Moreover the smaller the forest area, the higher will be public intention to conserve leading to a lower deforestation. To capture this impact of forests the forest stock is scaled by using GDP.

**ix. Exchange rate ( $X_{it}$ )**

Devaluation will encourage export and discourage imports. The devaluation will make agricultural outputs profitable leading to farmer's expansion to frontier forest land for more agricultural expansion. The sign of this variable is expected to be positive.

**x. Governance ( $Gov_{it}$ )**

Governance includes different institutional set up. The institutional setups will have an impact on the operation of environmental protection agencies. Such agencies will work more efficiently if there is good governance. The sign of this variable is assumed to be negative. The governance index in this study is collected from Freedom House, who has been collecting data on such indexes since 1972. The index included in the study is the summation of civil liberty index and political rights.

**xi. Corruption ( $Cor_{it}$ )**

Letiao (2006) has stated corruption can contribute to environmental degradation by taking. The sign for this variable is expected to be negative. The better corruption index the lesser deforestation. The corruption index used in this model is taken from the Heritage Foundation data set corresponding to freedom from corruption.

### **3.2 Sample**

This study takes SSA countries as a sample. The sample excludes countries with less than 5% of land under forest by adopting the argument of Martinez (1998). She argues that it is hypothesized that it has ceiling effect on the rate of deforestation related to accessibility are relative abundance.

### **3.3 Model Specification**

This study uses Panel data estimation. Bhattarai and Hamming (2002) explained that effect of institutional and policy variables can be revealed by cross – sectional analysis which provides wide variation of institutions. Panel data analysis allows the study of dynamic as well as cross sectional aspects of the problem. Because of this panel data is a better way of estimation to use.

Letiao (2006) argues that the issue whether the country effects are correlated with explanatory variables or not is important in deciding usage of fixed effects or random effects model. If country – specific characteristics are correlated with the explanatory variables random effects model will result in inconsistent results. Fixed effects model is preferred in such cases.

The following figure presents the framework of the model to be estimated in the study.

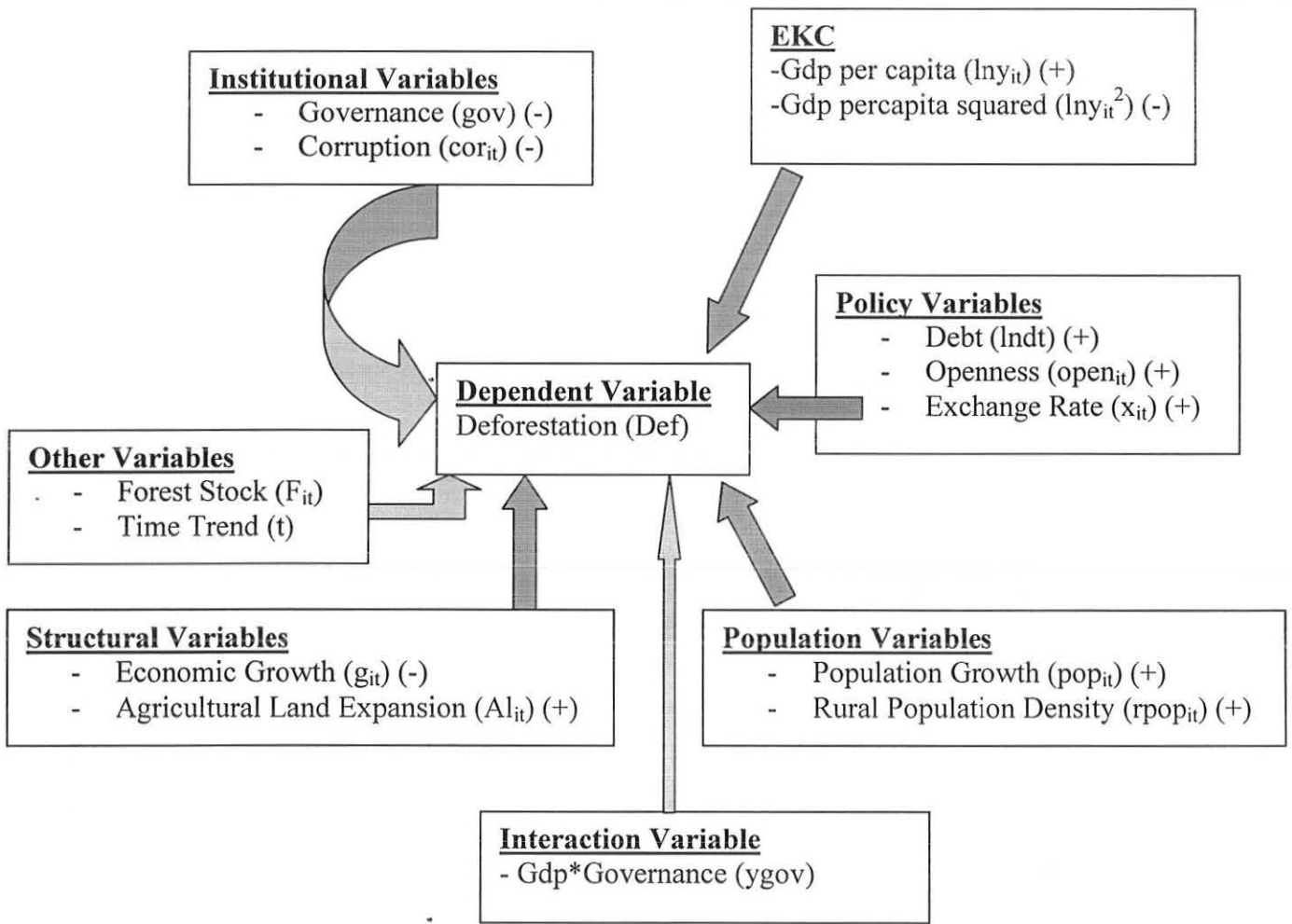


Figure 3.1: Framework of the Model Estimated

The model estimated combines the EKC and the Institutional models explained in Barbier (2001).

$$\text{EKC analysis: Def}_{it} = f(Y_{it}, Y_{it}^2; Z_{it}) \dots \dots \dots \dots \dots (3.1)$$

In a more specific way Shafik(1994) specified EKC model for some environmental indicators including deforestation. In this study Shafik has tried to estimate the relation between income and environmental indicators and to look the shape of the relationship using three approaches: log linear, quadratic, and cubic modes presented as follows:

$$\begin{aligned} E_{it} &= \alpha_0 + \alpha_1 \ln Y_{it} + \alpha_2 T_i + \alpha_3 F_i + e_{it} \\ E_{it} &= \beta_0 + \beta_1 \ln Y_{it} + \beta_2 (\ln Y_{it})^2 + \beta_3 T_i + \beta_4 F_i + e_{it} \dots \dots \dots \dots \dots (3.2) \\ E_{it} &= \phi_0 + \phi_1 \ln Y_{it} + \phi_2 (\ln Y_{it})^2 + \phi_3 (\ln Y_{it})^3 + \phi_4 T_i + \phi_5 F_i + e_{it} \end{aligned}$$

Where  $E_{it}$  = Environmental quality indicator

$Y_{it}$  = GDP Per capita

$T_i$  = Time trend

$F_i$  = Fixed effect for site – specific factors

$$\text{Institutional model: Def}_{it} = f(Q_{it}; Z_{it}) \dots \dots \dots \dots \dots (3.3)$$

Combining these two models we will have

$$\text{Def}_{it} = f(Y_{it}, Y_{it}^2, Q_{it}; Z_{it}) \dots \dots \dots \dots \dots (3.4)$$

The specific model which is estimated in this study is the combination of the EKC framework with population factors, selected policy variables and institutional factors:

$$\begin{aligned} Def_{it} &= \alpha_0 + \alpha_1 \ln Y_{it} + \alpha_2 (\ln Y_{it})^2 + \alpha_3 F_{it} + \alpha_4 Ale_{it} + \alpha_5 g_{it} + \alpha_6 pop_{it} + \alpha_7 rpop_{it} + \alpha_8 \ln Dt_{it} \dots \dots \dots \dots \dots (3.5) \\ &+ \alpha_9 Oppen_{it} + \alpha_{10} X_{it} + \alpha_{11} Gov_{it} + \alpha_{12} Cor_{it} + e_{it} \end{aligned}$$

Where Def = deforestation measured as annual average rate of forest change

Y = GDP per capita

g = economic growth rate

F = initial forest stock

Ale = agricultural land expansion

pop = population growth rate

rpop = rural population density

Dt = Government debt

Oppen = openness

X = Real exchange rate

Gov = Governance index

Cor = Corruption index

### 3.3.1 Model Estimations

Baltagi (2005) explained that panel regression models are different from a time series model in that it has a double subscript on its variables

$$y_{it} = \alpha + \beta X_{it}' + u_{it} \quad i = 1, 2, \dots, N \quad t = 1, 2, \dots, T \quad \dots \dots \dots (3.6)$$

Baltagi further explained that i denote households, firms or countries where t denotes the time. Thus, i capture the cross section while t captures the time series. There are various models of panel regression here we discuss the major ones. The disturbance term  $u_{it}$  is divided in two components: Unobservable individual effects ( $\mu_i$ ) and remainder disturbances ( $v_{it}$ ).

$$u_{it} = \mu_i + v_{it} \quad \dots \dots \dots (3.7)$$

Baltagi explains the panel data using estimations of firms' production function where  $Y_{it}$  will be output produced and  $\bar{X}_{it}$  measures inputs used in production.  $\mu_i$ , will measure unobservable entrepreneurial or managerial abilities. The remainder disturbances  $\nu_{it}$  can be taught as usual disturbances in the regression which vary with time and cross-sectional variables.

### ***3.3.1.1 Fixed Effects Model (The Least Squares Dummy Variables Model (LSDV))***

The fixed effects model assumes  $\mu_i$  to be a fixed parameter to be estimated and the remainder disturbances stochastic  $\nu_{it}$  with independently and identically distributed IID  $(0, \sigma_v^2)$  (Baltagi, 2005). Greene (2003) explained that the fixed effects approach takes  $\mu_i$  group specific constant term in the regression. Greene further explains the term fixed in this approach as follows:

*“The term “fixed” as used here indicates that the term does not vary over time, not that is non stochastic, which need not to be the case.”*

According to Greene (2003) kind of estimations assume that differences across units can be captured in differences in the constant term. This model also allows the unobserved individual effected to be correlated with the included variables. While each like unknown variable  $\mu_i$ , is taken as an unknown variable to be estimated. In a matrix form this models estimation can be presented as follows:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ X_n \end{bmatrix} \beta + \begin{bmatrix} 1 & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & 1 & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot & \cdot & 1 \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \\ \cdot \\ \cdot \\ \mu_n \end{bmatrix} + \begin{bmatrix} \nu_1 \\ \nu_2 \\ \cdot \\ \cdot \\ \nu_n \end{bmatrix} \dots \dots \dots \dots (3.8)$$

This model is usually referred as Least Square Dummy Variable (LSDV) model. Greene (2003) argues the term least square refers the method used to estimate it not the model it self. Baltagi (2005) stated to avoid dummy variable trap or perfect multicollinearity; we need to put a condition  $\sum_{i=1}^N \mu_i = 0$ .

**Fixed Effect Hypothesis Testing**

The joint significance of the dummies in this model can be tested with F-test with null hypothesis of  $H_0 : \mu_1 = \mu_2 = \dots = \mu_{N-1} = 0$ . The simple Chow test can be performed as follows

$$F_o = \frac{(RRSS - URSS)/(N-1)}{URSS/(NT - N - K)} \stackrel{H_0}{\sim} F_{N-1, N(T-1)-K} \quad \text{(Baltagi, 2005)} \quad \dots \dots \dots (3.9)$$

- Where RRSS = Restricted Residual Sum of Squares of OLS on Pooled model
- URSS = Unrestricted Residual Sum of Squares of LSDV regression
- N = number of groups
- T = total number of observations
- K = number of regressors in the model

If we accept the null hypotheses the efficient estimator is the pooled least squares.

### 3.3.1.2 Random Effects Model

This approach, unlike the previous approach, allows  $\mu_i$  to be random. In this approach  $\mu_i$  is individually and identically distributed (i.e.  $\mu_i \sim IID(0, \delta_\mu^2)$ ) and  $v_{it} \sim IID(0, \delta_v^2)$ . Further the approach assumes  $X_{it}$  to be independent of  $\mu_i$  and  $v_{it}$ ,  $\mu_i$  to be independent of  $v_{it}$  (Greene, 2003 and Baltagi, 2005).

$$E(u_{it} / X_{it}) = 0 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3.10)$$

This model has an advantage over the fixed effect model in preserving degree of freedom. In the fixed effects model as we have many variables included in the model estimated there is high loss of degree of freedom. This model can be viewed as regression with random constant term (Greene, 2003). The notation for these this approach is:

$$y_{it} = \alpha + \beta X_{it}' + \mu_i + v_{it} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3.11)$$

### 3.3.2 Specification Tests

The Hausman specific test designed by Hausman (1978) is most frequently utilized to test between fixed effects and random effects. Greene (2003) Stated that the dummy variables approach is costly in that it results in loss of degrees of freedom. The random effect may be inconsistent because of correlation between included variables and the random effect.

The Hausman (1978) test suggests comparison of  $\hat{\beta}_{GLS}$  and  $\tilde{\beta}_{within}$ , both of which are consistent under the null hypothesis,  $H_0: E(u_{it} / X_{it}) = 0$ , But they will have different probability limits under the alternative hypothesis (Baltagi, 2005). The importance factor in this test is the covariance matrix of the difference  $\hat{\beta}_{GLS} - \tilde{\beta}_{within}$ .

$$\text{var}(\hat{\beta}_{GLS} - \tilde{\beta}_{Within}) = \text{var}(\hat{\beta}_{GLS}) + \text{var}(\tilde{\beta}_{Within}) - \text{cov}(\hat{\beta}_{GLS}, \tilde{\beta}_{Within}) - \text{cov}(\tilde{\beta}_{Within}, \hat{\beta}_{GLS}) \dots (3.12)$$

Greene (2003) explains the Hausman's essential result as follows:

*“The covariance of an efficient estimator with its difference from an inefficient estimator is zero.”*

$$\text{Cov}(\hat{\beta}_{GLS} - \tilde{\beta}_{Within}, \tilde{\beta}_{Within}) = \text{cov}(\hat{\beta}_{GLS}, \tilde{\beta}_{Within}) - \text{var}(\tilde{\beta}_{Within}) = 0 \dots (3.13)$$

Or

$$\text{cov}(\hat{\beta}_{GLS}, \tilde{\beta}_{Within}) = \text{var}(\tilde{\beta}_{Within}) \dots \dots \dots (3.14)$$

Inserting the above result in equation (3.12) we can have the covariance matrix used in the test.

$$\text{var}(\hat{\beta}_{GLS} - \tilde{\beta}_{Within}) = \text{var}(\hat{\beta}_{GLS}) - \text{var}(\tilde{\beta}_{Within}) = \Psi \dots \dots \dots (3.15)$$

Greene (2003) presented the Chi-Square test based on the Wald test

$$W = \chi^2(k-1) = (\hat{\beta}_{GLS} - \tilde{\beta}_{Within})' \Psi^{-1} (\hat{\beta}_{GLS} - \tilde{\beta}_{Within}) \dots \dots \dots (3.16)$$

Under  $H_0$ , W has Chi-square distribution  $K-1$  degrees of freedom, where K is the number of variables estimated (Greene, 2003).

## *Chapter 4*

### *Results and Discussion*

This chapter discusses the results found in the estimation of the model this study focuses. The estimation is done in two ways. The first approach is applied by following Shafik (1994). This approach estimates each individual variable into a basic EKC model. This estimation process is believed to minimize the problem of loss of degrees of freedom. And further it helps us to look into individual impacts of the variables we are interested in on the EKC framework. The first part of this chapter discusses the descriptive statistics of the explanatory variables and statistical tests used in this study. The second part of the chapter discusses the individual equations estimated and the last part of the chapter discusses the full EKC model estimated with and without institutional variables.

#### *4.1 Descriptive statistics of variables and Statistical Tests*

##### *a. Descriptive Statistics*

Table 4.1 presents the descriptive statistics of the variables used in the model. The positive maximum value for deforestation implies that in the region there are countries with afforestation rather than deforestation. The maximum negative rate of deforestation is recorded for Burundi for the period 2001 to 2005. The high degree of afforestation is for Rwanda in the same period. The per capita for the region is in general very low. South Africa has the maximum level of per capita of \$8477.6 and the minimum for Liberia of \$295.05.

Cape Verde has the lowest forest stock of 3.6 hectares and Sudan has the maximum forest stock of 11,370 hectares. From the countries taken as a sample, Rwanda has both the minimum and the maximum population growth in the study period. Rwanda has also the maximum rural population density while Zambia has the minimum rural population density.

With the measurement of openness to the international world, Sierra Leone is less opened from the countries taken as a sample in this study. Liberia is the most opened country in the region. The exchange rate regime in the region is more or less fixed. Angola has the minimum exchange rate in 1995 and Madagascar has the maximum exchange rate in 2005.

In this study the researcher has used two measurements of institutional variables, the governance index and the corruption index. Nigeria in 1995, Burundi in 1995 and 1996 and Sudan for the whole period of study has the maximum score of governance. Nigeria in 1995 has the minimum score for the governance index. Regarding the corruption index, Nigeria in 2005 and Ghana in 2005 and 2006 has scored the maximum score and Nigeria in 1995 has scored the minimum.

The Skewness result shows except debt and governance all variables are positively skewed. We have used three tests to test the normality of the variables included in the study. All the three tests used imply that the variables included are normally distributed (The results of the tests are shown in ANNEX 2)

*Table 4.1 : Descriptive Statistics of Variables*

Variables	Minimum	Maximum	Mean	Median	Skewness	Kurtosis
Deforestation	-5.2	6.9	-0.727	-0.7	1.1256	10.4741
Ln(per capita income)	4.7140	9.0451	6.90	6.77	0.5867	3.5415
Forest stock	3.2	11369.83	957.2721	503.8342	3.5528	19.8915
Growth	-31.3	106.28	4.7151	4.4062	5.7637	79.3764
Agricultural land	8.0417	91.316	49.6405	47.152	0.0806	2.1355
Population growth	-1.7221	9.7561	2.7428	2.6451	2.5859	17.494
Rural population density	110.72	783.1	328.6581	286.5	0.5756	2.2788
Ln(debt)	17.418	24.3578	21.7898	21.9001	-0.274	2.9724
Openness	12.943	986.65	60.1657	40.993	9.1766	108.6823
Exchange rate	0	9344.29	825.8567	527.47	3.4745	16.2269
Governance	2	14	8.9724	9	-0.3729	2.1572
Corruption	7	70	25.5931	30	0.6345	2.9036

Note: sample size 33 for all variables except for debt which is 32 (excluding Namibia)

### b. Specification tests

The following figure shows the Hausman Specification test used to choose between the fixed effect and random effects model. The test result suggests that fixed effect is the appropriate model.

```
. hausman fe re
```

Note: the rank of the differenced variance matrix ( 11) does not equal the number of coefficients being tested ( 14); be sure this is what you expect, or there may be problems computing the test. Examine the output of your estimators for anything unexpected and possibly consider scaling your variables so that the coefficients are on a similar scale.

	Coefficients		(b-B) Difference	sqrt(diag(v_b-v_B)) S.E.
	(b) fe	(B) re		
lny	15.42185	11.40012	4.021733	1.504067
lny2	-1.240628	-.8468941	-.3937343	.1330848
fit	.000079	.0000255	.0000536	.0000159
t	-.0356241	-.0543058	.0186817	.0137487
alit	.0668687	.0339827	.032886	.0211127
git	.0123835	.0112577	.0011257	.
popit	-.5403288	-.5902635	.0499347	.
rpopit	-.0024623	.0000621	-.0025243	.0009666
lndt	-.6690998	-.6346121	-.0344877	.1503635
openit	.0024236	-.0024744	.004898	.
xit	-1.49e-07	.000015	-.0000151	.
gov	-.1592905	-.1180904	-.0412001	.
ygov	.0001042	.0000673	.0000369	7.15e-06
corit	.0022031	.0029387	-.0007356	.

b = consistent under Ho and Ha; obtained from xtreg  
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2( 11) = (b-B)'[(v\_b-v\_B)^(-1)](b-B)  
 = 27.04  
 Prob>chi2 = 0.0045  
 (v\_b-v\_B is not positive definite)

**Figure 4.1: Hausman Specification test**

Further to choose between the random effects test and the pooled OLS regression, test this study uses the Breusch and Pagan Lagrangian Multiplier (LM) test for random effects. As the following figure shows the test statistics suggests the random effects estimation is preferred than the pooled OLS Regression. The two tests combined suggest that fixed effect is better than the OLS regression.

. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

def[id,t] = Xb + u[id] + e[id,t]

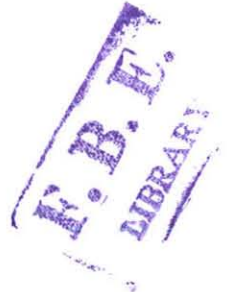
Estimated results:

	Var	sd = sqrt(Var)
def	2.293284	1.514359
e	.1843387	.4293468
u	1.021667	1.010776

Test: Var(u) = 0

chi2(1) = 600.80  
Prob > chi2 = 0.0000

**Figure 4.2: Breusch Pagan LM Test for Random Effects**



**c. Heteroskedasticity Test**

In this study we have applied the Breusch – Pagan test for heteroskedasticity discussed in Verbeek (2000). This study estimates the square of residual of the fixed effects model. The test statistics multiplies the  $R^2$  of auxiliary regression of this residual with explanatory variables used in the model by  $N(T-1)$ . The test statistics has a Chi-square distribution with  $J$  degrees of freedom, where  $J$  is the number of explanatory variables used in the auxiliary regression. We estimated the residual square on the explanatory variables and the  $R^2$  is found to be 0.7824. The test statistics becomes 258.192. The Chi-square statistic value at 5% significance level with 14 degrees of freedom is 23.68. This test rejects the null hypothesis of homoskedasticity. The full process is presented in ANNEX 5.

**d. Autocorrelation**

To test for autocorrelation, in this study we used the modified Durbin-Watson test designed by Bhagarva, Franzini and Narendranathan (1983). The test statistic is

$$dw_p = \frac{\sum_{i=1}^N \sum_{t=2}^T \left( \hat{\varepsilon}_{it} - \hat{\varepsilon}_{i,t-1} \right)^2}{\sum_{i=1}^N \sum_{t=1}^T \hat{\varepsilon}_{it}^2} \quad (\text{Verbeek, 2000})$$

The Durbin Watson statistic found to be 0.942 suggesting that there is a negative autocorrelation in the model estimated.

#### *e. Multicollinearity*

To check for the presence of Multicollinearity in the model we have used the variance covariance matrix presented in the ANNEX 3. The table implies that there is no major problem of Multicollinearity in the model. The correlation coefficient between the explanatory variables is less than 0.5 except for  $\ln y$  and  $\ln y^2$  which is usually more than 0.5.

### **4.2 Individual Models**

By following the steps of Shafik (1994) we have estimated the basic EKC model with the individual population, policy and institutional variables. Bhattarai and Hamming (2002) explained that this way of estimation avoids problem of multicollinearity in addition to its advantage of conserving the loss of degrees of freedom. As we have discussed in the previous part to cope up with the problem of hetroskedatsticity we used robust standard errors. Before the estimation process is done in the study outliers test is accomplished. In this respect the study is done on 33 SSA countries. Table 4.2 presents the result of this estimation. The whole result of the model estimated is presented in ANNEX 6. In all the models estimated the EKC hypothesis holds with statistically significant positive coefficient for the level variable and negative variable for the squared variable.

Equation 1 estimates the basic EKC model. The result shows that the EKC hypothesis holds for deforestation. This provides evidence that there is an inverted 'U' shaped relationship between per capita income and deforestation. In almost all the separate models estimated, the variable we used to control the effect of forest area (forest stock) is statistically insignificant with positive coefficient. This shows that countries with large forest cover have higher levels of deforestation. This result explains the fact that the larger the forest area the more abundant the resource becomes leading to a forest destruction. The time trend is statistically significant only in equation 2. The significant negative coefficient implies the rate of deforestation is declining through time.

The structural variables used in the estimation process, agricultural land expansion and economic growth, are estimated with the basic EKC model in equations 2 and 3. Agricultural land expansion is found to be an important driver of deforestation in the region. The result explains that agricultural land demand results in expansion of agriculture to frontier land and deforestation. Economic growth is estimated in equation 3. The coefficient is found statistically insignificant but with expected sign.

**Table 4.2: Individual Models Estimated**

Independent Variables	Equation (1)	Equation (2)	Equation (3)	Equation (4)
Constant	-13.716 (-2.47)**	-15.9905 (-3.66)***	-13.585 (-2.56)**	-15349 (-2.40)**
GDP per capita	4.3349 (2.37)**	2.4245 (1.67)*	4.1745 (2.37)**	5.2522 (2.58)***
GDP per capita Sq	-0.3547 (-2.32)**	-0.179 (-1.34)	-0.3324 (-2.23)**	-0.4386 (-2.65)***
Forest stock	0.0000555 (1.28)	0.0000952 (2.26)**	0.0000573 (1.33)	0.000079 (1.69)*
Time trend	0.0088 (0.63)	-0.0747 (-4.08)***	0.00319 (0.25)	0.0071 (0.50)
Agricultural land expansion		0.1586 (3.64)***		
Economic growth			-0.007449 (-1.26)	
Population growth				-0.2402 (-1.90)*
Rural population density				
Debt				
Openness				
Exchange rate				
Governance				
GDP*Governance				
Corruption				
R <sup>2</sup> Within	0.0153	0.1891	0.0226	0.1285
R <sup>2</sup> Between	0.0598	0.0235	0.0562	0.0858
R <sup>2</sup> Overall	0.0467	0.0157	0.0408	0.0466

Note: 1) Values in parenthesis are t-statistics; \* = significant at 10%. \*\* = significant at 5%, \*\*\* = significant at 1%

2) All models are estimated with robust standard errors.

*Table 4.2 continued*

Independent Variables	Equation (5)	Equation (6)	Equation (7)	Equation (8)
Constant	-15.1375 (-3.12)***	-13.2473 (-2.22)**	-31.4249 (-3.06)***	-13.696 (-2.46)**
GDP per capita	5.6416 (3.13)***	4.9003 (2.40)**	9.2952 (2.98)***	4.3278 (2.37)**
GDP per capita Sq	-0.4608 (-2.95)***	-0.4047 (-2.37)**	-0.7009 (-2.93)***	-0.3541 (-2.32)**
Forest stock	0.000075 (1.70)*	0.0000653 (1.45)	0.0000708 (1.56)	0.0000556 (1.28)
Time trend	0.0163 (1.07)	0.01264 (0.89)	0.0069 (0.51)	0.0086 (0.60)
Agricultural land expansion				
Economic growth				
Population growth				
Rural population density	-0.0079 (-3.15)***			
Debt		-0.0940 (-0.98)		
Openness			0.002583 (2.73)***	
Exchange rate				3.50e <sup>-06</sup> (0.33)
Governance				
GDP*Governance				
Corruption				
R <sup>2</sup> Within	0.1218	0.0187	0.0312	0.0153
R <sup>2</sup> Between	0.1191	0.0479	0.0317	0.0601
R <sup>2</sup> Overall	0.0848	0.0371	0.0226	0.0469

Note: 1) Values in parenthesis are t-statistics; \* = significant at 10%. \*\* = significant at 5%, \*\*\* = significant at 1%

2) All models are estimated with robust standard errors.

*Table 4.2 continued*

Independent Variables	Equation (9)	Equation (10)	Equation (11)	Equation (12)
Constant	-13.5173 (-2.49)**	-17.2656 (-2.46)**	-31.695 (-2.91)***	-49.69431 (-3.35)
GDP per capita	4.3094 (2.37)**	6.153 (2.52)**	9.5644 (2.93)***	16.3802 (3.42)***
GDP per capita Sq	-0.3538 (-2.32)**	-0.5439 (-2.58)**	-0.7307 (-2.94)***	-1.3319 (-3.49)***
Forest stock	0.0000559 (1.30)	-5.84e <sup>-06</sup> (-0.16)*	0.0000809 (1.78)*	-8.99e <sup>-06</sup> (-0.22)
Time trend	0.00853 (0.63)	0.00889 (0.64)	0.0124 (0.94)	0.01375 (1.00)
Agricultural land expansion				
Economic growth				
Population growth				
Rural population density				
Debt				
Openness				
Exchange rate				
Governance	-0.006655 (-0.35)	-0.0853 (-2.06)**		-0.1938 (-3.42)***
GDP*Governance		0.0000854 (2.73)***		0.000153 (3.51)***
Corruption			0.00158 (0.91)	0.0020351 (0.99)
R <sup>2</sup> Within	0.0154	0.0322	0.0324	0.0892
R <sup>2</sup> Between	0.0613	0.0320	0.0474	0.0280
R <sup>2</sup> Overall	0.0479	0.0224	0.0436	0.0204

Note: 1) Values in parenthesis are t-statistics; \* = significant at 10%. \*\* = significant at 5%, \*\*\* = significant at 1%

2) All models are estimated with robust standard errors.

Equations 4 and 5 present the population variables' estimation with the basic EKC model. The population growth variable is statistically significant with unexpected negative sign showing that population pressure results in slower deforestation process in the region. The other population variable, rural population density has a negative and statistically significant coefficient. The negative coefficient implies that places where the rural population pressure is high, the deforestation process is slow. Templton and Scherr (1999) explained that once rural population pressure increases to a sufficient level and forest becomes sufficiently scarce, society tends to improve forest protection.

Equations 6, 7, and 8 show estimation of the selected policy variables. In this estimation debt variable is found to be statistically insignificant with unexpected negative sign. This statistically insignificant result of debt is also found in Bhattarai and Hamming (2002). The Openness of a country leads to more deforestation as it is shown in equation 7 by the positive and statistically significant coefficient. Openness of a country to the international world encourages primary exports (which are typical in SSA). This will accelerates exploitation of frontier land utilization for production of such commodities and further deforestation. Exchange rate is found highly insignificant as it is shown in equation 8.

The institutional variables estimation is shown in equations 9 through to 12. With the inclusion of the institutional variables the EKC still holds. The governance variable is statistically insignificant when estimated with or without the interaction term (which formed by the product of GDP and the governance index) as it is shown in equation 9 and 10.

According to Bhattarai and Hamming (2002), the inclusion of the interaction variable helps us to isolate the net impact of government institutions on management of natural resources from income effect. The results show that better governance leads to efficient operation of forest protection programs and further lesser deforestation. The coefficient of the interaction variable which is formed by multiplying per capita income by governance index is positive and statistically significant. The result implies that the income effect on deforestation depends on the level of governance improvements. The corruption index is statistically insignificant with expected positive sign.

#### ***4.3 The Complete EKC model***

Table 4.3 provides the estimation of the complete EKC model. To capture the impact of institutional variable the models are estimated with and without the institutional variables. The statistical results of these models are shown in ANNEX 7.

The EKC framework holds in all of the complete models estimated. The level per capita income variable is positive and the squared variable is negative. This implies that there is an inverted 'U' shaped relationship between the per capita income and deforestation. The presence of the EKC curve suggests that development in early stages puts a pressure on forests results in more destruction. But as the development process continues, development will positively contribute to the improvement of forest resources. This result is online with the results found in Barbier (2001), Bhattarai and Hamming (2002).

**Table 4.3: Complete EKC Model**

Independent Variables	Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (5)
Constant	-39.478 (-3.29)***	-39.459 (-3.27)***	-52.362 (-4.05)***	-20.10141 (-1.78)*	-33.34874 (-2.55)**
GDP per capita	11.29792 (3.29)***	11.29076 (3.27)***	16.415 (4.33)***	10.12147 (3.40)***	15.42185 (4.09)***
GDP per capita Sq	-0.85807 (-3.12)***	-0.85733 (-3.09)***	-1.310491 (-4.29)***	-0.7824301 (-3.47)***	-1.240628 (-4.16)***
Forest stock	0.0001565 (2.62)***	0.0001563 (2.82)***	0.0000776 (1.59)	0.0001355 (3.07)***	0.000079 (1.91)*
Time trend	-0.04625 (-2.21)**	-0.04623 (-2.21)**	0.040609 (-2.04)**	-0.0388266 (-1.70)*	-0.0356241 (-1.74)*
Agricultural land expansion	0.11734 (2.61)***	0.11753 (2.59)***	0.10564 (2.45)**	0.0724335 (3.14)***	0.0668687 (2.81)***
Economic growth	0.000066 (0.01)	0.00001044 (0.01)	-0.002902 (-0.32)	0.0164696 (2.14)**	0.0123835 (1.89)*
Population growth	-0.2368 (-1.94)*	-0.2366 (-1.92)*	-0.2314 (-1.95)*	-0.5563422 (-6.82)***	-0.5403288 (-6.74)***
Rural population density	-0.0032 (-2.04)**	-0.0032 (-2.03)**	-0.0041 (-2.47)**	-0.0023171 (-1.24)	-0.0024623 (-1.36)
Debt	-0.08449 (-0.46)	-0.08575 (-0.45)	-0.09145 (-0.49)	-0.6387709 (-2.65)***	-0.6690998 (-3.08)***
Openness	0.00294 (2.44)**	0.00293 (2.42)**	0.00395 (3.14)***	0.0041334 (1.66)*	0.0024236 (0.94)
Exchange rate	-0.0000352 (-1.60)	-0.0000351 (-1.61)	-0.0000365 (-1.73)*	-2.04e <sup>-07</sup> (-0.01)	-1.49e <sup>-07</sup> (-0.01)
Governance		0.00140 (0.06)	-0.1176 (-3.15)***		-0.1592905 (-3.79)***
GDP*Governance			0.0001246 (3.90)***		0.0001042 (3.04)***
Corruption				0.0007291 (0.25)	0.0022031 (0.67)
Turning point	\$7194.61	\$7250.3	\$5247.49	\$6441.7	\$5003.7
R <sup>2</sup> Within	0.3226	0.3226	0.3538	0.5402	0.5701
R <sup>2</sup> Between	0.0838	0.0834	0.0856	0.0294	0.0319
R <sup>2</sup> Overall	0.0509	0.0506	0.0489	0.0055	0.0056

Note: 1) Values in parenthesis are t-statistics; \* = significant at 10%. \*\* = significant at 5%, \*\*\* = significant at 1%

2) All models are estimated with robust standard errors.

The initial forest stock variable has a positive and statistically significant variable implying higher forest areas can be vulnerable to high deforestation because of abundance. The time trend variable has negative and statistically significant coefficient in all the models estimated. Its result implies that the deforestation process is declining over time. This means that the trend of average deforestation rate is declining in the recent past.

In all the models estimated the agricultural land expansion is positive. The positive coefficient implies that with high pressure of land use for agricultural purpose the higher will be the deforestation (Ehui and Hentel, 1989)

Economic growth is found to be statistically significant in the last two equations. The estimated results imply that economic growth process in the region has played a role in the deforestation process. This positive relationship between economic growth and deforestation is also found in Shandra et al. (2008).

The population growth variable is found to have a negative relationship with deforestation in all the models estimated. This implies that places of higher population growth have slower deforestation process. This result is different from what the literature on the subject states.

The rural population density is statistically significant in all equations. The negative variable for the density of rural population implies that higher rural population pressures might lead to slower deforestation process. Bhattarai and Hamming (2002) also found same negative relationship between rural population density and deforestation. Templton and Scherr (1999) have also explained as rural population density raises the cost of land use. As this costs

increase people will look for better ways of managing resources which decrease the destruction of resources like forests.

The debt burden variable included in the model gives a result which is different from what we empirically have in this relationship, which is statistically significant in the last two models. The result implies that debt burden has a negative impact on the rate of deforestation.

The openness of a country to the international world can have a positive contribution to deforestation. The result of the model estimation process implies that openness has a positive relationship with deforestation in such a way that more open countries will have the more problem of deforestation.

The exchange rate variable in the model is insignificant in all types of the models estimated. The negative sign of exchange rate implies that strengthening the value of domestic currency minimizes the pressure of deforestation process.

The institutional variables included in the models provide an evidence for importance of such factors in slowing the deforestation process. The governance index is statistically insignificant when it is used with out the interaction term (equation 2). But the estimation of the governance index by controlling for the interaction variable makes the index statistically significant (equation 3). And the negative coefficient implies that better governance leads to lower rates of deforestation. This negative relationship between governance and deforestation is also found in Bhattarai and Hamming (2002), Deacon (1994) and Nelson et al. (2001). The

positive coefficient for the interactive term used in the study implies the income effect on deforestation depends on better performance of the governance.

The corruption index is statistically insignificant, but the negative coefficient provides evidence that higher level of corruption may fasten the rate of deforestation in the country.

The turning points calculated for each model are shown in the table. These turning points also imply the importance of governance and corruption in EKC framework. The presence of good governance results in early turning point of the curve before more damage is done to the resource. This shown by the lower turning point reported in equation 3. Thus the result implies that better governance makes the turning point happen faster than usual condition which might minimize the damage on the forest. The other important factor in this frame work is corruption. The turning point implies that corruption if not controlled may result in a turning point in which more damage is done to forests in under normal circumstances. This is shown in the turning points of equation 4 and equation 5. The turning points imply as almost all of the countries in the region are below this threshold income level the will be still more damage to the forest before the improvement starts to occur.

## *Chapter 5*

### *Conclusion and Policy Implications*

#### *5.1 Conclusion*

Deforestation is an environmental problem which has further created environmental degradations in developing countries. These environmental degradations include expanding desertification, degradation of plant and animal species etc. EKC analyses the relationship between economic development and environmental quality. The analysis tries to find a development path with minimum damage to the environment.

In this study the researcher has tried to look at the presence of EKC hypothesis for deforestation in the SSA. The researcher further tried to look in to the impact of institutional variables on this relationship. To look to this relationship the study uses the data from 1990 to 2005 for 33 SSA countries. The data is collected from FAO forest assessment (2005) and WDI (2008). The study uses annual forest cover change as a measure for deforestation, which a dependent variable, and selected population, structural and institutional variables with the basic EKC framework. The researcher has utilized the panel data estimation. The panel data kind of estimation is used because the methodology incorporates both the time series and cross sectional components. This will help us to see the dynamics of the relationship and its cross sectional aspect.

In the study it is found out that EKC relationship holds for deforestation, providing an inverted 'U' shaped relationship between per capita income and deforestation. The result in the study implies that movement of countries to higher levels of per capita income contributes positively

to forest resources. Both the structural variables used, agricultural land expansion and economic growth, has a positive relationship with deforestation. Both these variables can result in higher rates of forest clearing.

Regarding the population variables, the population growth has a positive relationship with deforestation implying that higher population pressures can increase the rate of deforestation. The rural population density variable has negative relationship with deforestation suggesting areas with high rural population pressure found to have less deforestation problems.

The selected policy variables used in the study has mixed results. Openness of a country is found to have positive relationship with deforestation while debt burden is found to have negative relationship with deforestation, which is found to be a result different from what the literature in the theory suggests. Unlike the two exchange rate is found to be statistically insignificant.

The study has also found out that institutional variables has important role to play in the deforestation process. Better governances lead to lower rates of deforestation. The governance factor has an important role to play in the income effect on deforestation. Corruption index even if it is found to be statistically insignificant it has a negative relationship with deforestation.

## *5.2 Policy Implications*

The presence of EKC relationship in the study implies that development is not bad for forests in the region. But the higher turning points of the curve show that it takes a long period of time to reach at that point. This is because most of the regions countries are very much below the turning point per capita income. Thus it is better to find ways of coping with deforestation. This can be done by promoting environmental promoting policies like reforestation.

Since governance is found to have negative relationship with deforestation, the researcher believes that improving governance in the region may provide an incentive for the better protection and management of forests. Governance is more concerned with functions of government institutions. The implication of the result in this study is that for better management of forest the quality of these institutions (which is expressed through the manner in which power is exercised) should be improved.

Many countries in the region are trying to make their economy more open to the international economy to cope up with the fast globalizing world. The study suggests that openness of a country has an important factor to the deforestation process in the region. The countries in the region are trying to make their economies open to the international market. But this policy measure is putting more pressure on forests. The researcher suggests that openness measures taken in the region should take the environment in to consideration.

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*ANNEX 1: List of Countries in the Sample*

Angola	Nigeria
Benin	Rwanda
Burkina Faso	Senegal
Burundi	Sierra Leone
Cameroon	South Africa
Cape Verde	Sudan
Central African Republic	Swaziland
Chad	Tanzania
Congo	Togo
Cote d'Ivoire	Uganda
Eritrea	Zambia
Ethiopia	
Gambia	
Ghana	
Guinea	
Guinea Bissau	
Kenya	
Liberia	
Madagascar	
Malawi	
Mali	
Namibia	

## ANNEX 2: Normality Tests for Explanatory Variables

. sktest def lny lny2 fit alit t git popit rpopit lndt openit xit gov corit

Skewness/Kurtosis tests for Normality				
Variable	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	joint Prob>chi2
def	0.000	0.000	.	0.0000
lny	0.000	0.055	18.90	0.0001
lny2	0.000	0.007	36.95	0.0000
fit	0.000	0.000	.	0.0000
alit	0.523	0.000	29.83	0.0000
t	1.000	0.000	.	0.0000
git	0.000	0.000	.	0.0000
popit	0.000	0.000	.	0.0000
rpopt	0.000	0.000	29.83	0.0000
lndt	0.035	0.939	4.45	0.1080
openit	0.000	0.000	.	0.0000
xit	0.000	0.000	.	0.0000
gov	0.004	0.000	33.04	0.0000
corit	0.000	0.856	16.13	0.0003

. swilk def lny lny2 fit alit t git popit rpopit lndt openit xit gov corit

Shapiro-wilk w test for normal data					
Variable	Obs	W	V	z	Prob>z
def	363	0.81682	46.237	9.081	0.00000
lny	363	0.96421	9.034	5.213	0.00000
lny2	363	0.93911	15.371	6.472	0.00000
fit	363	0.61266	97.771	10.855	0.00000
alit	363	0.97298	6.820	4.548	0.00000
t	363	0.98096	4.805	3.718	0.00010
git	363	0.57026	108.473	11.101	0.00000
popit	363	0.75401	62.092	9.779	0.00000
rpopt	363	0.92513	18.899	6.962	0.00000
lndt	352	0.98730	3.118	2.690	0.00357
openit	363	0.37031	158.945	12.006	0.00000
xit	363	0.54839	113.994	11.219	0.00000
gov	363	0.97453	6.430	4.408	0.00001
corit	317	0.95728	9.557	5.313	0.00000

. sfrancia def lny lny2 fit alit t git popit rpopit lndt openit xit gov corit

Variable	Shapiro-Francia w' test for normal data				
	Obs	w'	v'	z	Prob>z
def	363	0.81305	50.393	8.035	0.00001
lny	363	0.96408	9.681	4.802	0.00001
lny2	363	0.93917	16.398	5.857	0.00001
fit	363	0.60929	105.319	9.414	0.00001
alit	363	0.97550	6.604	4.022	0.00003
t	363	0.98171	4.929	3.418	0.00032
git	363	0.55795	119.158	9.641	0.00001
popit	363	0.74765	68.023	8.601	0.00001
rpopt	363	0.92760	19.515	6.201	0.00001
lndt	352	0.98791	3.171	2.490	0.00639
openit	363	0.36199	171.980	10.309	0.00001
xit	363	0.54630	122.298	9.689	0.00001
gov	363	0.97438	6.907	4.114	0.00002
corit	317	0.96479	8.425	4.489	0.00001

### ANNEX 3: Correlation Coefficient Test

```
. correlate lny lny2 fit alit git popit rpopit openit xit lndt corit gov
(obs=308)
```

	lny	lny2	fit	alit	git	popit	rpopt	openit	xit	lndt	corit
lny	1.0000										
lny2	0.9982	1.0000									
fit	0.1822	0.1694	1.0000								
alit	0.2377	0.2501	-0.1399	1.0000							
git	0.0480	0.0398	0.1841	-0.0347	1.0000						
popit	-0.2938	-0.2943	-0.1753	0.0857	0.2804	1.0000					
rpopt	-0.2878	-0.2750	-0.3841	0.1441	0.0020	0.2503	1.0000				
openit	0.5450	0.5391	0.0145	0.2897	0.0199	-0.1209	-0.0962	1.0000			
xit	-0.2043	-0.2105	0.0041	0.0959	-0.0285	-0.0376	0.0675	-0.0617	1.0000		
lndt	0.2500	0.2456	0.4506	0.1705	0.0314	-0.2254	-0.2813	-0.1298	0.0698	1.0000	
corit	0.2656	0.2697	0.0135	0.0902	-0.0932	-0.2783	-0.0996	-0.0250	0.0726	0.2916	1.0000
gov	-0.0539	-0.0663	0.2882	0.0893	-0.0161	0.1114	0.0497	0.1456	-0.2156	0.1078	-0.3249
		gov									
gov	1.0000										

## ANNEX 4: Hausman Specification Test

```
. xtreg def lny lny2 fit t alit git popit rpopit lndt openit xit gov ygov corit, fe
```

```
Fixed-effects (within) regression          Number of obs   =       308
Group variable: id                        Number of groups =        29

R-sq:  within = 0.5701                    Obs per group:  min =         9
        between = 0.0319                  avg =       10.6
        overall = 0.0056                  max =        11

corr(u_i, Xb) = -0.7428                    F(14,265)       =       25.10
                                                Prob > F        =       0.0000
```

def	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lny	15.42185	3.088152	4.99	0.000	9.341414	21.50229
lny2	-1.240628	.2392713	-5.19	0.000	-1.711743	-.7695137
fit	.000079	.0000502	1.57	0.117	-.0000199	.0001779
t	-.0356241	.0193531	-1.84	0.067	-.0737295	.0024813
alit	.0668687	.0232749	2.87	0.004	.0210416	.1126959
git	.0123835	.0062397	1.98	0.048	.0000979	.0246691
popit	-.5403288	.0448493	-12.05	0.000	-.6286351	-.4520225
rpopt	-.0024623	.0013924	-1.77	0.078	-.0052038	.0002793
lndt	-.6690998	.2091116	-3.20	0.002	-1.080831	-.2573682
openit	.0024236	.0036772	0.66	0.510	-.0048166	.0096638
xit	-1.49e-07	.0000349	-0.00	0.997	-.0000689	.0000686
gov	-.1592905	.0375388	-4.24	0.000	-.2332028	-.0853781
ygov	.0001042	.000029	3.59	0.000	.0000471	.0001613
corit	.0022031	.0037395	0.59	0.556	-.0051597	.0095659
_cons	-33.34874	11.49524	-2.90	0.004	-55.98237	-10.7151
sigma_u	2.2301648					
sigma_e	.42934678					
rho	.96426142	(fraction of variance due to u_i)				

```
F test that all u_i=0:      F( 28, 265) =    63.03          Prob > F = 0.0000
```

```
. estimates store fe
```

```
. xtreg def lny lny2 fit t alit git popit rpopit lndt openit xit gov ygov corit, re
```

```
Random-effects GLS regression           Number of obs   =       308
Group variable: id                     Number of groups =       29

R-sq:  within = 0.5369                 *           Obs per group: min =       9
      between = 0.0094                                     avg =      10.6
      overall  = 0.0449                                     max =      11

Random effects u_i ~ Gaussian           Wald chi2( 14)   =      259.69
corr(u_i, X) = 0 (assumed)             Prob > chi2      =       0.0000
```

def	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lny	11.40012	2.697121	4.23	0.000	6.113856	16.68638
lny2	-.8468941	.1988447	-4.26	0.000	-1.236622	-.4571658
fit	.0000255	.0000476	0.53	0.593	-.0000679	.0001188
t	-.0543058	.0136205	-3.99	0.000	-.0810014	-.0276102
alit	.0339827	.0097966	3.47	0.001	.0147817	.0531837
git	.0112577	.0066377	1.70	0.090	-.001752	.0242675
popit	-.5902635	.0454667	-12.98	0.000	-.6793767	-.5011503
rpopt	.0000621	.0010022	0.06	0.951	-.0019023	.0020264
lndt	-.6346121	.145322	-4.37	0.000	-.9194381	-.3497861
openit	-.0024744	.0038547	-0.64	0.521	-.0100295	.0050807
xit	.000015	.0000372	0.40	0.687	-.0000579	.0000878
gov	-.1180904	.0387963	-3.04	0.002	-.1941297	-.0420511
ygov	.0000673	.0000281	2.39	0.017	.0000122	.0001224
corit	.0029387	.0039182	0.75	0.453	-.0047409	.0106183
_cons	-23.82777	9.923337	-2.40	0.016	-43.27715	-4.378389
sigma_u	1.0107756					
sigma_e	.42934678					
rho	.84714946	(fraction of variance due to u_i)				

```
. estimates store re
```

```
. hausman fe re
```

Note: the rank of the differenced variance matrix ( 11) does not equal the number of coefficients being tested ( 14); be sure this is what you expect, or there may be problems computing the test. Examine the output of your estimators for anything unexpected and possibly consider scaling your variables so that the coefficients are on a similar scale.

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
	(b) fe	(B) re		
lny	15.42185	11.40012	4.021733	1.504067
lny2	-1.240628	-.8468941	-.3937343	.1330848
fit	.000079	.0000255	.0000536	.0000159
t	-.0356241	-.0543058	.0186817	.0137487
alit	.0668687	.0339827	.032886	.0211127
git	.0123835	.0112577	.0011257	.
popit	-.5403288	-.5902635	.0499347	.
rpopt	-.0024623	.0000621	-.0025243	.0009666
lndt	-.6690998	-.6346121	-.0344877	.1503635
openit	.0024236	-.0024744	.004898	.
xit	-1.49e-07	.000015	-.0000151	.
gov	-.1592905	-.1180904	-.0412001	.
ygov	.0001042	.0000673	.0000369	7.15e-06
corit	.0022031	.0029387	-.0007356	.

b = consistent under H<sub>0</sub> and H<sub>a</sub>; obtained from xtreg  
 B = inconsistent under H<sub>a</sub>, efficient under H<sub>0</sub>; obtained from xtreg

Test: H<sub>0</sub>: difference in coefficients not systematic

```
chi2( 11) = (b-B)'[(V_b-V_B)^(-1)](b-B)
          = 27.04
Prob>chi2 = 0.0045
(V_b-V_B is not positive definite)
```

## ANNEX 5: Heteroskedasticity Test

```
. reg ei2 lny lny2 fit t alit git popit rpopit lndt openit xit gov ygov corit
```

Source	SS	df	MS			
Model	3682.79435	14	263.056739	Number of obs =	308	
Residual	1024.12575	293	3.49530971	F( 14, 293) =	75.26	
Total	4706.92009	307	15.3319873	Prob > F =	0.0000	
				R-squared =	0.7824	
				Adj R-squared =	0.7720	
				Root MSE =	1.8696	

ei2	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lny	-54.31107	3.376968	-16.08	0.000	-60.95726	-47.66488
lny2	4.137274	.247579	16.71	0.000	3.650015	4.624532
fit	-.0005812	.0000978	-5.95	0.000	-.0007736	-.0003888
t	.1657528	.0385934	4.29	0.000	.0897974	.2417083
alit	-.0340641	.0070489	-4.83	0.000	-.0479369	-.0201912
git	.0020625	.0238738	0.09	0.931	-.0449233	.0490483
popit	.9723008	.1458383	6.67	0.000	.6852774	1.259324
rpopt	-.0013881	.0008454	-1.64	0.102	-.0030518	.0002757
lndt	.269142	.1224148	2.20	0.029	.0282183	.5100658
openit	-.0324373	.0076658	-4.23	0.000	-.0475243	-.0173503
xit	.0000376	.0000791	0.47	0.635	-.0001181	.0001932
gov	.2887709	.0871241	3.31	0.001	.1173026	.4602392
ygov	-.0001022	.0000507	-2.01	0.045	-.0002021	-2.36e-06
corit	-.0062577	.0096684	-0.65	0.518	-.0252859	.0127706
_cons	171.2046	11.64699	14.70	0.000	148.2823	194.127

H<sub>0</sub>: Homoskedastic residuals

H<sub>1</sub>: Heteroskedasticity

$$\begin{aligned} \text{Test statistic : } R^2(N(T-1)) &= 0.7824 (33(11-1)) \\ &= 258.92 \end{aligned}$$

$$\text{Tabulated value } \chi^2_{14,0.950} = 23.68$$

As the test statistic is greater than the tabulated value we reject the null hypothesis of homoskedasticity.

## ANNEX 6: Individual Models

. xtreg def lny lny2 fit t, fe robust

```

Fixed-effects (within) regression      Number of obs   =      363
Group variable: id                    Number of groups =      33

R-sq:  within = 0.0153                Obs per group:  min =      11
        between = 0.0598                avg =      11.0
        overall = 0.0467                max =      11

corr(u_i, Xb) = -0.5464                F(4,326)        =      2.28
                                           Prob > F         =      0.0606

```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	4.334912	1.827606	2.37	0.018	.7395217	7.930301
lny2	-.3546628	.1527318	-2.32	0.021	-.6551272	-.0541984
fit	.0000555	.0000432	1.28	0.200	-.0000295	.0001404
t	.0088158	.0138975	0.63	0.526	-.0185242	.0361558
_cons	-13.71602	5.549252	-2.47	0.014	-24.63288	-2.799152
sigma_u	1.7076334					
sigma_e	.65242658					
rho	.87262053	(fraction of variance due to u_i)				

. xtreg def lny lny2 fit t alit, fe robust

```

Fixed-effects (within) regression      Number of obs   =      363
Group variable: id                    Number of groups =      33

R-sq:  within = 0.1891                Obs per group:  min =      11
        between = 0.0235                avg =      11.0
        overall = 0.0157                max =      11

corr(u_i, Xb) = -0.9173                F(5,325)        =      6.30
                                           Prob > F         =      0.0000

```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	2.424506	1.449932	1.67	0.095	-.4279299	5.276942
lny2	-.1788606	.1329822	-1.34	0.180	-.4404752	.082754
fit	.0000952	.0000421	2.26	0.025	.0000123	.0001781
t	-.0747005	.0183282	-4.08	0.000	-.1107574	-.0386435
alit	.158625	.0435387	3.64	0.000	.0729717	.2442783
_cons	-15.99054	4.363544	-3.66	0.000	-24.5749	-7.406186
sigma_u	3.7203106					
sigma_e	.59297504					
rho	.97522469	(fraction of variance due to u_i)				



```
. xtreg def lny lny2 fit t rpopit, fe robust
```

```
Fixed-effects (within) regression      Number of obs   =      363
Group variable: id                    Number of groups =      33

R-sq:  within = 0.1218                Obs per group:  min =      11
      between = 0.1191                    avg =      11.0
      overall = 0.0848                    max =      11

corr(u_i, Xb) = -0.7976                F(5,325)       =      4.26
                                          Prob > F       =      0.0009
```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	5.641608	1.802713	3.13	0.002	2.095149	9.188068
lny2	-.4608041	.156205	-2.95	0.003	-.7681046	-.1535036
fit	.000075	.0000442	1.70	0.091	-.000012	.000162
t	.0163104	.0152309	1.07	0.285	-.0136533	.046274
rpopt	-.0078706	.0024991	-3.15	0.002	-.0127871	-.0029541
_cons	-15.13747	4.859024	-3.12	0.002	-24.69658	-5.578356
sigma_u	2.3391202					
sigma_e	.61707894					
rho	.93493355	(fraction of variance due to u_i)				

```
. xtreg def lny lny2 fit t lndt, fe robust
```

```
Fixed-effects (within) regression      Number of obs   =      352
Group variable: id                    Number of groups =      32

R-sq:  within = 0.0187                Obs per group:  min =      11
      between = 0.0479                    avg =      11.0
      overall = 0.0371                    max =      11

corr(u_i, Xb) = -0.5683                F(5,315)       =      1.68
                                          Prob > F       =      0.1394
```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	4.900327	2.044229	2.40	0.017	.8782574	8.922396
lny2	-.4047262	.1709593	-2.37	0.019	-.7410927	-.0683597
fit	.0000653	.0000452	1.45	0.149	-.0000236	.0001542
t	.0126464	.0141604	0.89	0.372	-.0152145	.0405073
lndt	-.094034	.0962631	-0.98	0.329	-.2834339	.0953659
_cons	-13.24733	5.957684	-2.22	0.027	-24.96922	-1.525448
sigma_u	1.7767443					
sigma_e	.66257841					
rho	.87791133	(fraction of variance due to u_i)				

. xtreg def lny lny2 fit t openit, fe robust

```

Fixed-effects (within) regression      Number of obs   =       363
Group variable: id                    Number of groups =       33

R-sq:  within = 0.0312                Obs per group: min =      11
      between = 0.0317                  avg =      11.0
      overall = 0.0226                  max =      11

corr(u_i, Xb) = -0.5444                F(5,325)        =       2.76
                                          Prob > F         =      0.0184

```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	9.295169	3.115411	2.98	0.003	3.166251	15.42409
lny2	-.7009097	.2394053	-2.93	0.004	-1.171889	-.22993
fit	.0000708	.0000455	1.56	0.121	-.0000187	.0001602
t	.0068741	.0134525	0.51	0.610	-.0195908	.0333391
openit	.0025826	.0009471	2.73	0.007	.0007193	.0044458
_cons	-31.42491	10.28424	-3.06	0.002	-51.65699	-11.19283
sigma_u	1.7331495					
sigma_e	.64813934					
rho	.87730786	(fraction of variance due to u_i)				

. xtreg def lny lny2 fit t xit, fe robust

```

Fixed-effects (within) regression      Number of obs   =       363
Group variable: id                    Number of groups =       33

R-sq:  within = 0.0153                Obs per group: min =      11
      between = 0.0601                  avg =      11.0
      overall = 0.0469                  max =      11

corr(u_i, Xb) = -0.5468                F(5,325)        =       1.83
                                          Prob > F         =      0.1068

```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	4.327831	1.829631	2.37	0.019	.7284163	7.927245
lny2	-.3540686	.1528034	-2.32	0.021	-.6546772	-.05346
fit	.0000556	.0000434	1.28	0.202	-.0000298	.0001409
t	.0085617	.0142219	0.60	0.548	-.0194168	.0365403
xit	3.50e-06	.0000105	0.33	0.738	-.0000171	.0000241
_cons	-13.69595	5.559728	-2.46	0.014	-24.63355	-2.75835
sigma_u	1.7079694					
sigma_e	.65342461					
rho	.87232416	(fraction of variance due to u_i)				



. xtreg def lny lny2 fit t corit, fe robust

```

Fixed-effects (within) regression      Number of obs   =       317
Group variable: id                    Number of groups =        30

R-sq:  within = 0.0324                Obs per group:  min =         9
        between = 0.0474                avg =       10.6
        overall = 0.0436                max =        11

corr(u_i, Xb) = -0.6576                F(5,282)        =        2.30
                                         Prob > F         =       0.0450

```

(Std. Err. adjusted for clustering on id)

def	Coeff.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	9.564403	3.260856	2.93	0.004	3.145697	15.98311
lny2	-.7307282	.2486172	-2.94	0.004	-1.220109	-.2413473
fit	.0000809	.0000455	1.78	0.076	-8.60e-06	.0001703
t	.0124266	.0132875	0.94	0.350	-.0137287	.0385819
corit	.0015849	.0017381	0.91	0.363	-.0018363	.0050062
_cons	-31.695	10.80812	-2.93	0.004	-52.96982	-10.42017
sigma_u	1.8163569					
sigma_e	.62438995					
rho	.89431792	(fraction of variance due to u_i)				

. xtreg def lny lny2 fit t gov ygov corit, fe robust

```

Fixed-effects (within) regression      Number of obs   =       317
Group variable: id                    Number of groups =        30

R-sq:  within = 0.0892                Obs per group:  min =         9
        between = 0.0280                avg =       10.6
        overall = 0.0204                max =        11

corr(u_i, Xb) = -0.7160                F(7,280)        =        2.75
                                         Prob > F         =       0.0088

```

(Std. Err. adjusted for clustering on id)

def	Coeff.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	16.38023	4.790439	3.42	0.001	6.950382	25.81008
lny2	-1.331895	.3821649	-3.49	0.001	-2.084176	-.579614
fit	-8.99e-06	.0000408	-0.22	0.826	-.0000894	.0000714
t	.0137546	.0137251	1.00	0.317	-.0132628	.0407721
gov	-.1938004	.0565953	-3.42	0.001	-.3052068	-.0823941
ygov	.0001529	.0000436	3.51	0.001	.0000671	.0002387
corit	.0020351	.0020568	0.99	0.323	-.0020136	.0060838
_cons	-49.69431	14.85575	-3.35	0.001	-78.93744	-20.45118
sigma_u	1.999352					
sigma_e	.6079237					
rho	.91537144	(fraction of variance due to u_i)				

## ANNEX 7: Complete EKC Model

```
. xtreg def lny lny2 fit t alit git popit rpopit lndt openit xit, fe robust
```

```
Fixed-effects (within) regression      Number of obs   =      352
Group variable: id                    Number of groups =      32

R-sq:  within = 0.3226                 Obs per group:  min =      11
        between = 0.0838                avg =      11.0
        overall = 0.0509                max =      11

corr(u_i, Xb) = -0.8672                F(11,309)       =      4.13
                                                Prob > F        =      0.0000
```

(Std. Err. adjusted for clustering on id)

def	Robust				
	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
lny	11.29792	3.433254	3.29	0.001	4.54241 18.05344
lny2	-.8580657	.2754482	-3.12	0.002	-1.400057 -.3160742
fit	.0001565	.0000551	2.84	0.005	.000048 .000265
t	-.0462505	.0209312	-2.21	0.028	-.0874363 -.0050647
alit	.1173425	.044931	2.61	0.009	.028933 .205752
git	.000066	.0094262	0.01	0.994	-.0184816 .0186136
popit	-.2367567	.1219584	-1.94	0.053	-.4767306 .0032172
rpopt	-.0032194	.0015793	-2.04	0.042	-.0063269 -.0001119
lndt	-.0844976	.1843599	-0.46	0.647	-.4472573 .2782621
openit	.0029391	.0012032	2.44	0.015	.0005717 .0053066
xit	-.0000352	.000022	-1.60	0.110	-.0000784 7.97e-06
_cons	-39.47829	12.01187	-3.29	0.001	-63.1137 -15.84288
sigma_u	2.9964073				
sigma_e	.55581213				
rho	.96673691	(fraction of variance due to u_i)			



```
. xtreg def lny lny2 fit t alit git popit rpopit lndt openit xit gov ygov, fe robust
```

```
Fixed-effects (within) regression      Number of obs   =      352
Group variable: id                    Number of groups =      32

R-sq:  within = 0.3538                  Obs per group:  min =     11
        between = 0.0856                  avg =           11.0
        overall = 0.0489                  max =           11

corr(u_i, Xb) = -0.8531                  F(13,307)       =     4.22
                                          Prob > F        =     0.0000
```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	16.41528	3.790172	4.33	0.000	8.957283	23.87329
lny2	-1.310491	.3054086	-4.29	0.000	-1.91145	-.7095317
fit	.0000776	.0000488	1.59	0.113	-.0000185	.0001737
t	-.0406092	.0198581	-2.04	0.042	-.0796845	-.0015339
alit	.1056408	.0431859	2.45	0.015	.0206629	.1906187
git	-.0029022	.0091869	-0.32	0.752	-.0209795	.0151751
popit	-.2314491	.1187079	-1.95	0.052	-.4650331	.002135
rpopt	-.0040872	.0016527	-2.47	0.014	-.0073392	-.0008352
lndt	-.0914531	.1856203	-0.49	0.623	-.4567021	.2737958
openit	.0039511	.0012568	3.14	0.002	.001478	.0064243
xit	-.0000365	.0000211	-1.73	0.085	-.000078	5.09e-06
gov	-.1175783	.037346	-3.15	0.002	-.1910648	-.0440917
ygov	.0001246	.000032	3.90	0.000	.0000617	.0001875
_cons	-52.36211	12.93572	-4.05	0.000	-77.816	-26.90822
sigma_u	2.8712384					
sigma_e	.54462429					
rho	.96527004	(fraction of variance due to u_i)				

```
. xtreg def lny lny2 fit t alit git popit rpopit lndt openit xit corit, fe robust
```

```
Fixed-effects (within) regression      Number of obs   =      308
Group variable: id                    Number of groups =      29

R-sq:  within = 0.5402                Obs per group: min =      9
        between = 0.0294                avg =      10.6
        overall = 0.0055                max =      11

corr(u_i, Xb) = -0.7234                F(12,267)       =      7.98
                                         Prob > F         =      0.0000
```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust - Std. Err.	t	P> t	[95% Conf. Interval]	
lny	10.12147	2.973826	3.40	0.001	4.26634	15.9766
lny2	-.7824301	.2254581	-3.47	0.001	-1.226332	-.3385283
fit	.0001355	.0000441	3.07	0.002	.0000486	.0002223
t	-.0388266	.0227798	-1.70	0.089	-.0836774	.0060242
alit	.0724335	.0230825	3.14	0.002	.0269867	.1178803
git	.0164696	.0077063	2.14	0.033	.0012968	.0316424
popit	-.5563422	.0816124	-6.82	0.000	-.7170278	-.3956565
rpopt	-.0023171	.0018632	-1.24	0.215	-.0059855	.0013513
lndt	-.6387709	.2412004	-2.65	0.009	-1.113668	-.1638742
openit	.0041334	.0024911	1.66	0.098	-.0007714	.0090382
xit	-2.04e-07	.0000167	-0.01	0.990	-.0000331	.0000327
corit	.0007291	.0028996	0.25	0.802	-.0049799	.006438
_cons	-20.10141	11.29484	-1.78	0.076	-42.3397	2.136877
sigma_u	2.1578111					
sigma_e	.44231849					
rho	.95967561	(fraction of variance due to u_i)				

```
. xtreg def lny lny2 fit t alit git popit rpopit lndt openit xit gov ygov corit, fe robust
```

```
Fixed-effects (within) regression      Number of obs   =      308
Group variable: id                    Number of groups =      29

R-sq:  within = 0.5701                Obs per group:  min =      9
        between = 0.0319                avg =      10.6
        overall = 0.0056                max =      11

corr(u_i, Xb) = -0.7428                F(14,265)      =      8.15
                                         Prob > F        =      0.0000
```

(Std. Err. adjusted for clustering on id)

def	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
lny	15.42185	3.772813	4.09	0.000	7.993346	22.85035
lny2	-1.240628	.2981008	-4.16	0.000	-1.827576	-.653681
fit	.000079	.0000414	1.91	0.058	-2.55e-06	.0001606
t	-.0356241	.0205209	-1.74	0.084	-.0760287	.0047806
alit	.0668687	.0237757	2.81	0.005	.0200554	.1136821
git	.0123835	.0065534	1.89	0.060	-.0005198	.0252867
popit	-.5403288	.080112	-6.74	0.000	-.6980658	-.3825919
rpopt	-.0024623	.0018135	-1.36	0.176	-.006033	.0011085
lndt	-.6690998	.216906	-3.08	0.002	-1.096178	-.2420214
openit	.0024236	.0025785	0.94	0.348	-.0026533	.0075005
xit	-1.49e-07	.0000159	-0.01	0.993	-.0000315	.0000312
gov	-.1592905	.0420029	-3.79	0.000	-.2419924	-.0765885
ygov	.0001042	.0000342	3.04	0.003	.0000368	.0001716
corit	.0022031	.0032897	0.67	0.504	-.0042742	.0086804
_cons	-33.34874	13.05328	-2.55	0.011	-59.05008	-7.64739
sigma_u	2.2301648					
sigma_e	.42934678					
rho	.96426142	(fraction of variance due to u_i)				

## Declaration

I, the undersigned, declare that this is my original work and has not been presented for a degree in any university and that all sources of material used for the thesis has been duly acknowledged.

Examiner's comments have been duly incorporated.

## Declared by:

Name: Abducaziqe Ahmed

Signature: 

Date: June 30, 2009

## Confirmed by Advisor:

Name: Christine Fawell - Symon

Signature: 

Date: July 1, 2009