Economic Growth and Environmental Quality in Ethiopia: An Environmental Kuznets Curve Approach

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This is to certify that the thesis prepared by Gelagay Yeneneh, entitled: *Economic Growth and Environmental Quality in Ethiopia: An Environmental Kuznets Curve Approach* and submitted in partial fulfilment of the requirements for the Degree of Master of Sciences in Economics (Resource and Environmental Economics) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Abstract

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In an attempt to examine the growth-environment relationship in general, and in order to investigate an environmental Kuznets curve (EKC) for carbon dioxide (CO2) emission in particular, this study employs data spanning from 1981 to 2013. The Johansen co-integration test and error correction model (ECM) techniques were applied to capture both long-run relationships and short run dynamics in our system. The estimation results from these two techniques confirm the existence of EKC for CO2 emission in Ethiopia. In order to capture the effect of international trade, the study incorporates the ratio of manufacturing export to manufacturing gross domestic product (GDP) and the ratio of manufacturing import to manufacturing GDP. The estimated parameters for these two variables are found to have statistically significant effect. The econometrics procedure, however, does not show which factor actually contributes for a reduced emission. Thus, an increase in per capita income alone should not be considered as the solution of environmental problems. It needs environmental policies, regulations and/or standards in combination with strong institutions to enact the environmental policies. Hence, in the analysis of the growth-environment relationship, future research should focus on incorporating variables representing environmental policies, international trade, sectoral output composition of the economy or democracy.

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Acronyms

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criteria
ARDL	Auto-Regressive Distributed Lag
BAU	Business as Usual
BOD	Biochemical Oxygen Demand
CDIAC	Carbon Dioxide Information Analysis Center
CH_4	Methane
CIT	Cost, Insurance, and Freight
CO	Carbon monoxide
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide equivalent
CRGE	Climate Resilient Green Economy
CUSUM	Cumulative Sum of Recursive Residuals
ECM	Error Correction Model
ECT	Error Correcting Term
EKC	Environmental Kuznets Curve

FDI	Foreign Direct Investment
FDRE	Federal Democratic Republic of Ethiopia
FOB	Freight on Board
GDP	Gross Domestic Product
GEMS	Global Environmental Monitoring System
GLS	Generalized Least Squares
GHGs	Greenhouse Gases
IBRD	International Bank for Reconstruction and Development/ the World Bank
INDC	Intended Nationally Determined Contribution
LULUCF	Land Use, Land Use-Change and Forestry
$MtCO_{2e}$	Metric tons of carbon dioxide equivalent
N_2O	Nitrous Oxide
NO_X	Oxides of Nitrogen
PM_{10}	Particulate Matter
SO_2	Sulfur Dioxide
UECM	Unrestricted Error Correction Model
UNEP	United Nations Environment Programme

UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VAR	Vector Auto-regressive
VECM	Vector Error Correction Model
Wrt	With respect to

CHAPTER ONE

Introduction

1.1.Background

Economic activities need to use resources, and according to the law of thermodynamics[1], the use of resources in the production of goods and provision of services inevitably produce wastes (Stern, 2004). Rahman and Pora (2014) state this fact as, "we get our primary resources from the environment and throw up our pollution onto that" (P.86). In addition to this, the environmental resource base upon which all economic activities ultimately dependent on are finite, and imprudent use of them may pass the irreversibility threshold level (Arrow *et al*. 1995). On the basis of these facts, scholars try to explain the relationship between the environment and income level. The environmental Kuznets curve (EKC) is a hypothesis used to explain this relationship. It is borrowed from Kuznets (1955) who hypothesized that income inequality first rises and then falls as economic development[2] proceeds (Stern, 2004). At the early stage of economic growth environmental degradation and pollution will increase, but as income per capita rises the trend reverses and environmental quality will improve (Arrow *et al*. 1995; Stern, 2004; Deacon and Norman, 2004). It means that the environmental impact indicator is an inverted –U function of income per capita (Arrow *et al*. 1995; Stern, 2004). Deacon and Norman (2004) explain this phenomenon by asserting that, "the pursuit of economic growth and a cleaner environment in the

[1] According to the first law of thermodynamics, energy efficiency is defined in terms of %age of energy transferred for useful purpose. The second law on the other hand limits the efficiency of all practical systems (i.e.100% efficient practical system is not possible). Hence the input energy can be utilized in to two ways: (1) work done-useful output and waste-useless output degraded environment (Kumar, no date)

[2] In this paper economic development and/or economic growth is represented by an increase in per capita income.

same time frame need not work against one another. Instead, growth eventually leads to greening overtime, even if it does not appear to do so immediately" (P.2).

Acceptance of the EKC hypothesis implies that, along a country's development path at the earlier stage of development, environmental degradation is inevitable, but at later stage there will be significant improvement in environmental condition (Panayotou, 1993). In the earlier stages of economic development, increased pollution is regarded as an acceptable side effect of economic growth; this is because peoples in poor countries cannot afford to emphasize environmental quality (amenities) over material wellbeing (Arrow *et al*. 1995). However, when basic needs for food, water, clothing and shelter are satisfied and societies get richer, peoples give attention to the importance of the environment in total welfare as a result environmental quality will improve (Grossman and Krueger, 1991; Beckerman, 1992; Arrow *et al*. 1995; Dasgupta et al. 2002).

There are different justifications or explanations for the Kuznets curve pattern relationship between economic growth and the environment (an environmental indicator). At early stage of economic development, the relative increase in environmental pressure is higher than income growth and becomes lower at higher income level (de Bruyn *et al*, 1998; Dinda, 2004). Panayotou (1993) elaborates this as follows;

> *At low levels of development both the quantity and quality of environmental degradation is limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As economic development accelerates with the intensification of agriculture and other resource extraction and the takeoff of industrialization, the rates of resource depletion begin to exceed the rates of resource regeneration, and waste generation increases in quantity and toxicity. At higher levels of development, structural change towards information intensive industries and services coupled with increased environmental awareness, enforcement of regulations, better*

> *technology and higher environmental expenditures results in gradual decline of environmental degradation (P.1).*

While industrialization and agricultural modernization may initially lead to increased pollution, factors such as positive income elasticities for environmental quality, changes in the composition of production and consumption, increasing levels of education and environmental awareness, and more open political systems may cause a reduced emission or degradation at least for some pollutants (Selden and Song, 1994). An alternative explanation is: the EKC pattern income-environment relationship may be seen as the progression of economic development from clean agrarian economy to polluting industrial economy to clean service economy enhanced through the transfer of clean technology from high income countries to low income countries (Stagl, 1999). Pollution involves externalities and internalizing externalities need strong institutions to implement regulations which can be achieved at higher income levels (Andreoni and Levinson, 2001).

The problem arises as the EKC hypothesis works only for some types of pollutants and some countries during specific periods and does not hold for all pollutants and all countries or income levels (Akbostanci et al., 2009). On the one hand, some pollutants are a natural byproduct of economic activities and tend to grow as economic activity expands (Grossman and Krueger, 1991). On the other hand, the costs of some pollutants such as solid wastes, transnational pollution or greenhouse gases can be externalized (meaning the private benefits of averting damage are small). If this is the case, economic growth and/or higher income brings less degradation only where environmental quality directly affects human welfare and it will result in steady deterioration otherwise (Shafik and Bandyopadhyay, 1992).

When we take trade in to account, the observed EKC pattern environment-income relationship might result from displacement of pollution instead of pollution abatement. As suggested by Stern *et al* (1996) the inverted U- curve may be the result of changes in international trade specialization; poor countries specialize in material (labor and natural resource) intensive production and rich countries specialize in material extensive (human capital intensive activities) production without altering their consumption pattern. If this is the case, environmental effects are being displaced from one country to another rather than reduced (Ekins, 1997; de Bruyn, 1997). “Import substitution related reduction in environmental pressure should not be counted as an environmental gain” (Stagl, 1999, P.7). Likewise, developed countries export their pollution intensive production process to less developed countries. If the downward portion of the EKC is due to pollution exporting, then the process of environmental improvement will not be replicable (indefinitely) as the world’s poorest countries will lack other poorer countries coming behind them to export their pollution (or to relocate their pollution intensive activities) (Grossman and Krueger, 1995; Ekins, 1997; Andreoni and Levinson, 2001). So, this paper intends to represent trade by the ratio of manufacturing export to manufacturing GDP and the ratio of manufacturing import to manufacturing GDP separately, in order to capture the effects of both pollution displacement and exporting of pollution.

1.2. Statement of the Problem

Since economic growth is the prime focus of any economic policy, national and international laws designed to promote economic growth and international trade liberalization are not in a position to give adequate emphasis on the impacts of those policies on the environment (Arrow *et al*, 1995; Rahman and Pora, 2014). Arrow *et al* (1995) emphasizes this issue by asserting that, "economic liberalization and other policies that promote gross national products growth are not substitutes for environmental policy" (P.521). For them, what matters most is the content of growth (composition of inputs and outputs) which is mostly determined by the economic institutions within which human activities are conducted. For instance, reduction in trade barriers will affect the environment by expanding the scale of economic activity, by altering the composition of economic activities and by bringing about a change in the techniques of production (Grossman and Krueger, 1991). Thus, it is necessary to estimate or assess the relationship between economic activity and environmental quality to come up with appropriate economic and environmental policies which are helpful to keep the resilience of ecological systems.

Starting from the work of Grossman and Krueger (1991), the first attempt to systematically explain the relationship between income and the environment, the EKC concept came into environmental economics (Bhattarai and Hammig, 2001). Thereafter, a number of studies have been conducted to test the EKC hypothesis for different environmental indicators using different models. Some studies estimate the reduced form equations; for instance, (Grossman and Krueger, 1995), where the environmental impact indicator is a simple quadratic function of the level of income. The reduced form EKC shows, for whatever reason, there is a correlation (or not) between environmental degradation and per capita income in a society (Kolstad, 2005).

Although the estimates from the reduced form model have the advantage of showing the net effect of income changes on the quality of the environment, it is not clear why the estimated relationship between income and an environmental indicator exists (Grossman and Krueger, 1995). It inadequately captures the complex factors (like the effects of translocation of dirty industries, international trade and quality of institutions to enforce environmental regulation) underlying the relationship between income and environmental pressure (de Bryun et al, 1998). Hence, estimated regressions from this model reflect correlation rather than a causal mechanism by which the growth process affects the environment (Cole *et al*, 1997). Because of this deficiency of the reduced form EKC model to explain the income- environment relationship, it is better to analyze the structural EKC model in order to capture factors other than income which affect environmental quality in the process of growth and/ or development. But, it does not mean that the structural model is free from shortcomings. “The equations from the structural model have not been adequately specified in theoretical contributions, which makes it unclear what kind of variables have to be included in the model” (de Bruyn, 1997, P.488). Hence, expanding the reduced form model (the single equation model) by adding variables from the structural model representing structural change of an economy, international trade or democracy is the second best alternative in the analysis of the growth-environment relationship in the process of economic development of a country.

Most studies conducted to test the EKC hypothesis for various environmental impact indicators uses cross-country panel data. However, in a cross-country specification it is assumed that, the peak (turning point) of an inverted –U shaped income-pollution curve occurs at the same income level for all countries considered in the study. That is, estimates from cross-national panel data do not capture the dynamic process through which economic growth is de-linked from environmental pressure in individual countries (de Bruyn, 1998). In addition to this, most of the time, the trade variable is represented by the ratio of the sum of exports and imports to income; this variable captures total trade and may not reflect the differential competition between imports and exports[3] (Agras and Chapman, 1999). Thus, focus on within country specification with appropriate representation of the trade variable is better. This is because the purpose of the EKC hypothesis is to answer the question of how environmental quality evolves as a country develops (Deacon and Norman, 2004). This allows the shape of the pollution- income relationship to be country specific. With this specification one need to control country attributes that change during the sample period.

The environmental thermodynamics and the irreversibility threshold level of the resource base of an economy implies that, the importance of knowing the growth-environment interaction is not questionable no matter whether the country is developing or developed. Although a number of cross-national studies have been done by taking Ethiopia as one of the sample countries for different environmental indicators[4], only two studies (to the best of the author's knowledge) by Lamessa (2015) and Endeg (2015) try to examine the EKC hypothesis using within country specifications for Ethiopia. These studies have taken carbon dioxide as an environmental indicator. While Endeg (2015) confirms the existence of EKC for CO_2 emission, Lamessa (2015) rejects it. They represent the trade variable by trade openness. However, trade openness cannot capture (show) the effects of pollution displacement and pollution exporting associated with international trade. Thus, in this study the trade variable is represented by the ratio of

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[3]Suri and Chapman (1998) represents trade, by the ratio of manufacturing export to manufacturing GDP and the ratio of manufacturing import to manufacturing GDP separately
[4] Some of the growth-income relationship studies in which Ethiopia is incorporated as one of the sample countries are; Grey and Sadoff, 2007; Sahli and Rejeb, 2015; Bhattarai and Hammig, 2001; Shahpouri et al, 2016; Al Sayed and Sek, 2013

manufacturing export to manufacturing GDP, and by the ratio of manufacturing import to manufacturing GDP. In addition to this, the study incorporates industrial share of GDP as explanatory variable in order to capture the environmental effect of the structural change in the output composition of the economy.

1.3. Objective of the Study

The general objective of this study is to examine the relationship between growth and environmental quality in Ethiopia based on environmental Kuznets curve approach. It is specifically directed to investigate the Environmental Kuznets Curve (EKC) for $\boldsymbol{CO_2}$ emission.

1.4. Significance of the Study

The Ethiopian economy is highly dependent on agriculture; more than 80% of the population, in one way or another, depends on agriculture for its livelihood (Dacon and Hill, 2009). Carbon dioxide (CO_2) emission causes climate change and the agriculture sector is prone to the problem of climate change. Hence, dealing about CO_2emission and economic growth is appropriate in order to take the necessary measures in cooperation with the rest of the world, to reduce the negative effect of climate change resulting from economic growth through its higher emission. In addition, this paper pays special attention for technical and structural factors (both theoretically and empirically) which will contribute a lot positively or negatively to CO_2emission. So, this paper will have relevance as it adds something to the existed literature on the relationship between income and the environment in Ethiopia.

1.5. Scope of the study

This is a country level study (Ethiopia) and uses time series data for both dependent and explanatory variables starting from 1981 to 2013. Though different scholars have taken a number of environmental quality indicators to examine the growth- environment relationship in the process of economic development, this study takes CO_2 emission as an environmental quality indicator.

1.6. Limitations of the Study

From the econometric procedure of this study we have found the EKC relationship for CO_2 emission. However, this result does not show which factor exactly contributes for the decrease in CO_2 emission as per capita income increases. Thus, even if our econometrics procedure shows the existence of EKC for CO_2 emission, it is limited to show the origin (which factor does exactly contribute for this change?) of the change in emission. The decomposition method does exactly this. Unfortunately, the data needed to perform decomposition analysis (sectoral CO_2 emission and the corresponding sectoral GDP data) is not available. In addition to this, we were interested to incorporate corruption index in our econometrics procedure as a proxy for the quality of institutions to enforce environmental policies, regulations and/or standards. However, the available observation for this variable is insufficient to be analyzed in time series econometrics. Thus, this study is short of capturing direct technique effects. It captures technique effects indirectly through squared GDP per capita.

1.7. Organization of the Study

The rest of the chapters are organized as follows: the next chapter (chapter two) reviews both theoretical and empirical literature about the growth-environment relationship. Chapter three discusses issues related to data and methodology. Both the descriptive and econometrics analysis results and discussion are presented in chapter four. Finally, chapter five concludes and provides some implications.

Chapter Two

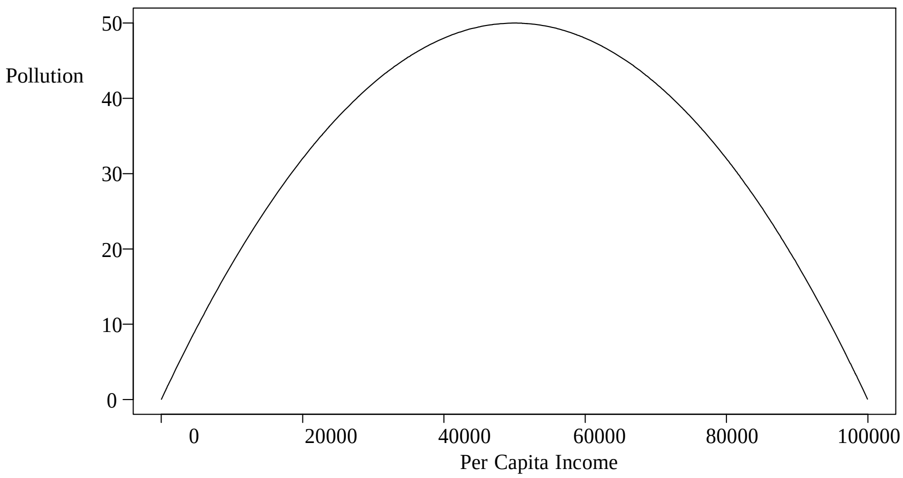
Literature Review

2. 1. Theoretical Literature

2.1.1. The Environmental Kuznets Curve

The environmental Kuznets curve (EKC) is an empirical phenomenon which shows that how some environmental problems (degradation or pollution) increase and then decrease with rising per capita incomes (McConnell, 1997). It is hypothesized that, at early stage of development both per capita income and environmental degradation and/or pollution increases but, as economic development proceeds structural change towards information intensive industries, increased environmental awareness, enforcement of environmental regulations and better technology results in gradual decline of environmental degradation (Panayotou, 1993). This results in an inverted-U shaped relationship between economic growth and environmental quality as represented in figure 2.1.

Figure 2.1: Stylized Environmental Kuznets Curve



Source: Carson (2010, p.4)

Panayotou (1993) summarizes the factors in which the state of natural resource and the environment in a country is dependent into the following five main categories; (a) the level of economic activity or size of the economy; (b) the sectoral structure of the economy; (c) the vintage of technology; (d) the demand for environmental amenities; and (e) the conservation and environmental expenditures and their effectiveness. A variety of theoretical models by Dinda (2005), Forster (1972; 1973), Lopez (1994), Selden and Song (1995), John and Pecchenino (1994), John et al (1995), McConnell (1997), and Lopez and Mitra (2000) provide explanations for this empirical regulatory (EKC) though different in some assumptions and model specifications. These models are different in how pollution is generated, the form of the utility function, whether the pollution externality is internalized and so on. Let us look at some of them;

The choice of any model is for analytical convenience. The theoretical models what we will discuss in this section are different ways to justify the relationship between economic growth and environmental quality in the process of economic development.

Though not explicit from the point of view of EKC, Forster (1972; 1973) provides us with theoretical explanation for the growth-environment relationship. Forster's 1972 model assumes production as a linearly separable concave function of capital (K) and pollution (P). It means that the marginal product of capital is independent of the level of pollution and vice-versa. Further the model assumes the society devotes a constant proportion, s, of total output to investment in productive capital. Higher capital accumulation produces higher pollution. The marginal product of capital is positive but diminishing while the marginal product of pollution is negative and increasing in magnitude. The goal is to determine the steady sate value of both capital accumulation and pollution which make the evolution of this hypothetical economy (given by the following two equations) zero.

The evolution of this hypothetical economy is;

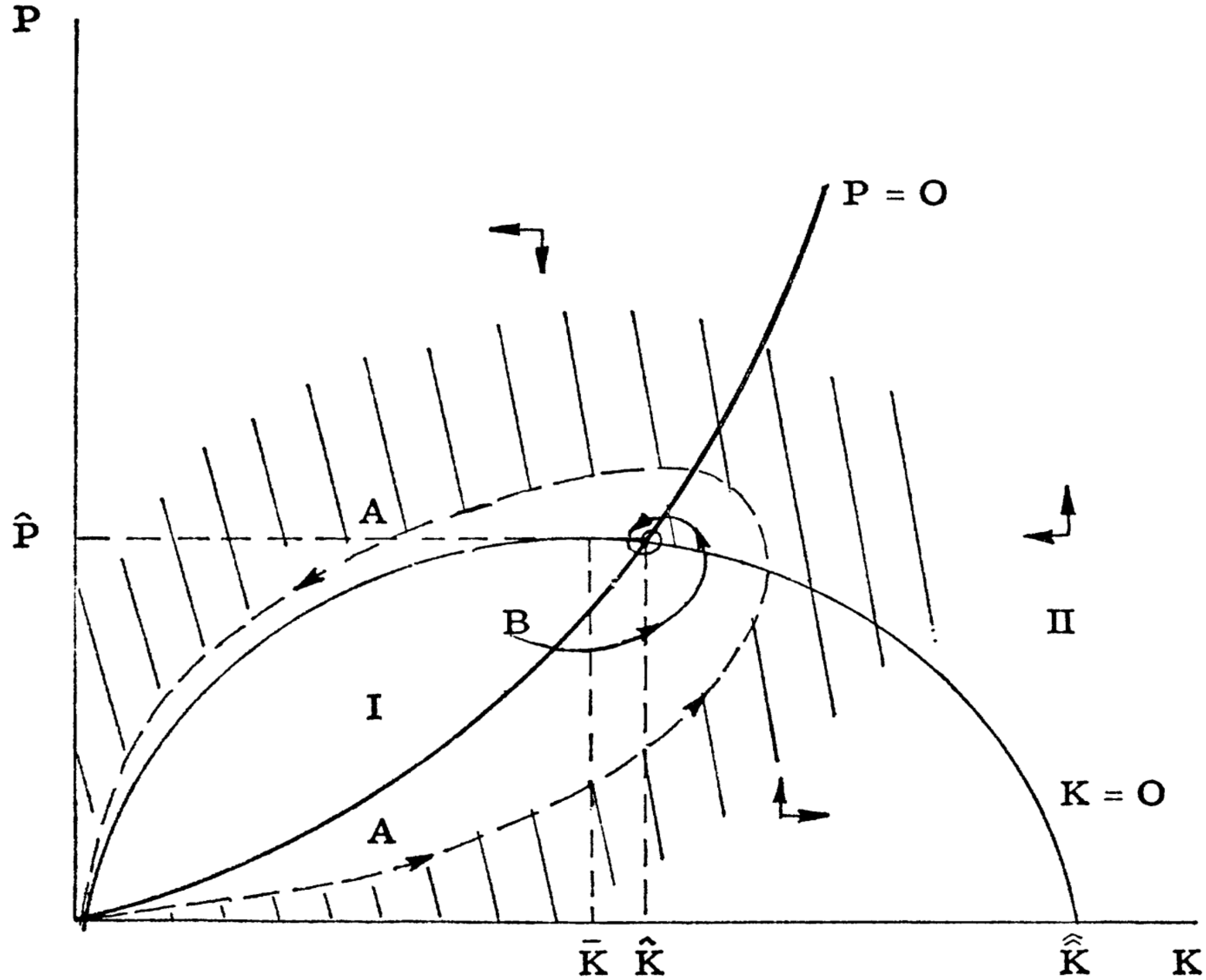
$$\dot{K} = s\emptyset(K, P) - \delta K; K(0) = K_0 \qquad (2.1)$$

$$\dot{P} = g(K) - \alpha P; P(0) = P_0$$

(2.2)

Where $\dot{K}$ and $\dot{P}$ is the evolution of capital accumulation and pollution over time respectively, δ is the exponential rate of capital depreciation and α captures the exponential rate of pollution decay's over time. The evolution of this hypothetical economy is depicted in a phase diagram to test different trajectories towards the steady state capital and pollution level.

Figure 2.2: Different trajectories towards the steady state capital and pollution level



Source: Forster (1972, P.283)

For constant K, $\dot{K}$ is a decreasing function of pollution; hence above $\dot{K} = 0$, $\dot{K} < 0$ and $\dot{K} > 0$ below $\dot{K} = 0$. On the other hand, for fixed levels of P, $\dot{P}$ is an increasing function of K; hence, $\dot{P} > 0$ to the right of $\dot{P} = 0$ and $\dot{P} < 0$ to the left of $\dot{P} = 0$.

$\widehat{K}$ and $\hat{P}$ are the values of capital and pollution for which equation (2.1) and (2.2) becomes zero simultaneously. Alternatively, $\widehat{K}$ and $\hat{P}$ are the steady state values of capital and pollution, respectively.

The phase space is divided in two regions I and II by the trajectory A. this trajectory separates stable paths from unstable paths. If the initial conditions are such that the system is in the shaded region II, then the system will not tend toward the equilibrium ($\widehat{K}$, $\hat{P}$). Trajectory B in region I is a trajectory which tends to the equilibrium ($\widehat{K}$, $\hat{P}$). "Even if pollution is not actively controlled by the community, it is possible that the economy will equilibrate, that is, move to a steady state in terms of the pollution level as well as the capital stock"(Forster, 1972, P.284).

Dinda (2005) explains the inverted U-shaped relationship between income and environmental degradation using endogenous growth model framework. The model assumes a closed economy in which production generates pollution and capital is used both for production and abatement (to upgrade the environment). Environment E, understood as a stock variable, affects both production and utility of the representative agent. The representative agent maximizes her present value of utility given by;

$$\text{Maximize } W = \int_0^\infty e^{-\rho t} U\big(C(t), E(t)\big) dt;\ U_{C>0}, U_{E>0;} \qquad (2.3)$$

$$U_{CC<0}, U_{EE<0}; U_{CE>0}$$

Where C, E, and ρ(>0) are consumption, stock of the environment (representing the stock of natural resources: land, air, water, flora and fauna, etc.), and rate of time preference respectively. Production function of the economy is given by;

$$Y = f\big(K_{y,} E\big);\ f_k > 0, f_E > 0; f_{kk} < 0, f_{EE} < 0 \qquad (2.4)$$

Where $K_{y,}$ denotes capital stock (physical and human) used in production and E is environmental stock as usual and also captures the productivity effect of environmental quality. Pollution is a fixed proportion of output and let its rate be β that is;

$$P = \beta Y, \beta > 0 \tag{2.5}$$

The quality of the environment (E) is endogenous and depleted gradually by the flow of the pollutants P, as

$$\dot{E} = -P = -\beta f(K_y, E) \tag{2.6}$$

This implies that the environmental stock (E) is decreasing over time and as t→∞, E→0. Since the environmental quality is an input for production, $f\left(K_y, 0\right) = 0$, the economy will collapse. Thus, "pollution affects production by damaging the inputs used to produce the output". Here, abatement is necessary to maintain environmental quality. Abatement needs some capital, say K_E. The model assumes that abatement is dependent only on man-made (physical and human capital) like production. Thus, abatement is given by

$$A = h(K_E) \tag{2.7}$$

So, net change to the environmental stock E over time is: $\dot{E} = A - P$. At each point in time the representative agent allocates her stock of capital ($K = K_y + K_E$) between production and abatement activity.

Let, $\theta = K_y/K$, which implies that $K = \theta K + K_E \Rightarrow K_E = (1 - \theta)K$; at any time t, $\theta(t)$ portion of capital is used in production and the remaining $(1 - \theta(t))$ for abatement (or to upgrade the environment).

Initially, environmental quality deteriorates as society does not recognize the importance of the environment for economic activity and capital will be used only for commodity production. However, at latter stage of development it recognizes its importance and starts to invest part of its capital for abatement. This is the basis for EKC.

> *The policy variable θ (allocation of capital) plays the vital role for controlling environmental quality. In the process of economic development, allocation of capital for abatement activity monotonically rises over time and halts at optimum or steady sate. Thus, generally the abatement activity becomes strong enough to restore environmental quality. It will be strong only when a sufficient investment takes place in the abatement sector, then environmental quality improves. This is the basis for U- shaped relationship between environmental quality and economic growth (Dinda, 2005, P. 409).*

Selden and Song (1995) derive the J curve for abatement and an inverted-U curve for pollution using the neoclassical environmental growth model of Forster[5]. The social planner's problem is to select trajectories for K, C, E, and (implicitly) P in order to maximize discounted (present value) utility.

$$max \int_0^\infty e^{-\rho t}\, U\big(C, P(K,E)\big)dt, \qquad (2.8)$$

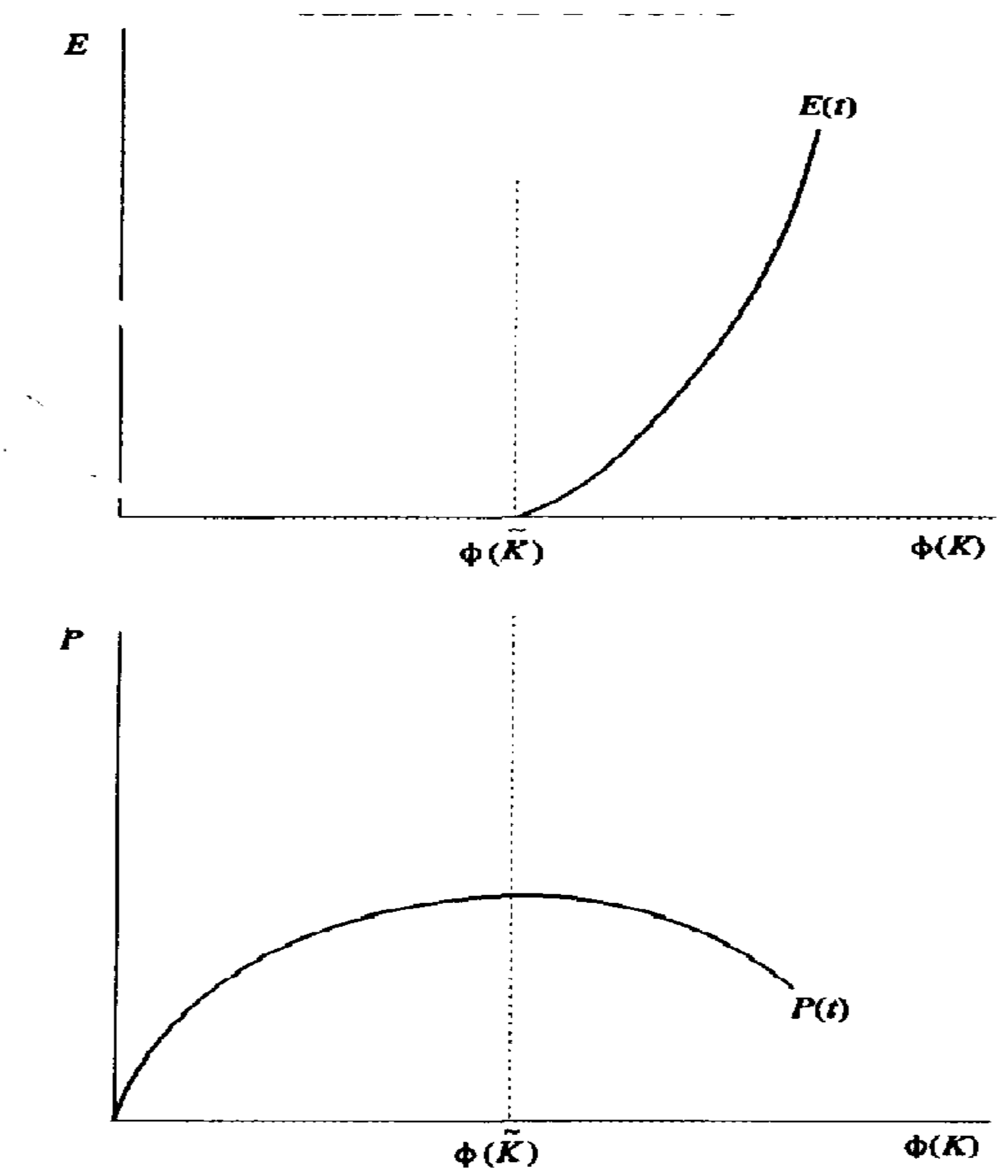
$$subject\ to\ \dot{K} = \emptyset(K) - \delta K - C - E, \text{ and } E \geq 0$$

Where, C is consumption, K is capital, E is abatement activity, P is pollution, and ρ is the rate of time preference.

---

[5] In Forster's model, pollution is a linearly separable function of the capital stock and the level of pollution control expenditure ($P(t) = P(K(t), E(t)$).The social welfare at any time is measured by a linearly separable function of consumption and pollution($U(C,P) = U_1(C) + U_2(P)$), $U'_1 > 0, U''_1 < 0$ and$U'_2, U''_2 < 0$. The community devotes output for consumption (C), investment in the capital stock (I), and to investment in pollution control (E). The model also assumes output as a function of only of the capital stock- $\emptyset(K)$ Forster (1973).

Figure 2.3: the J-curve for abatement and an inverted-U for pollution



Source: Selden and Song (1995, P.166)

In the derivation of the J curve for abatement, Selden and Song (1995) assume an initial corner solution at $E = 0$, given that both consumption and pollution are likely to be low at the earliest stage of development. E is increasing only, "once development has created enough consumption and enough environmental damage to merit expenditure on abatement".

The bottom panel of figure 2.3 depicts an inverted-U curve where P(t) is graphed against $\emptyset(K)$. In the above figure pollution declines once capital stock K(t) exceeds $\widetilde{K}$(t). $\widetilde{K}$(t) is the level of capital accumulation at which abatement activity starts. Thus, the possibility of an inverted U curve for pollution exists.

John and Pecchenino (1994), and John *et al* (1995) use overlapping generation models to analyze the extent to which environmental external effects are internalized. The models assume that, agents live for two periods, working while young and consuming while old. The young allocates their wage, w_t between saving for old age consumption and investment in environmental maintenance[6]. Furthermore, young agents have preferences defined over consumption in old age (C_{t+1}), and an index of the quality of the environment when they consume (E_{t+1}). While consumption degrades the environment, their investment in environmental quality improves it.

The model by John and Pecchenino (1994) assumes a zero population growth rate and normalizes the size of each generation to unity. In this model environmental quality evolves according to the following equation;

$$E_{t+1} = (1-b)E_t - \beta c_t + \gamma m_t;\ \beta > 0, \gamma > 0 \qquad (2.9)$$

Where βc_t is degradation of the environment as a result of consumption of the old at t, γm_t is environmental improvement as a result of actions taken by the young at t. Those alive at date t are represented by a one-period lived government whose responsibility is the provision of the public good, environmental quality. The government levies lump-sum taxes on the young to achieve the desired level of environmental maintenance. In conclusion, "a growing economy that

[6] In order to focus on the choice between investment in physical capital and investment in the environment, the model assumes that, agents do not consume in youth do not drive utility from the environment in youth (John and Pecchenino, 1994).

moves from zero to positive maintenance will exhibit environmental quality that deteriorates initially and later improves" (John and Pecchenino, 1994.P.1401).

On the other hand, the model by John *et at* (1995), assumes a population growth rate of 'N' ($N_t = (1+n)N_{t-1}$) and represented by a short or long-lived government. The quality of the environment is determined by the following equation.

$$E_{t+1} = (1-b)E_t - \beta N_{t-1}c_t + \gamma N_t m_t;\ \beta > 0, \gamma > 0 \tag{2.10}$$

Where $\beta N_{t-1}c_t$ is degradation of the environment by the consumption of the old at t, $\gamma N_t m_t$ environmental improvement from government programs funded by tax revenues at t. In this model the short lived government internalizes "the current period externality the young imposes on themselves when they are old by not taking into account the effect of their actions on environmental quality". Thus, the role of the short-lived government is to provide a public good (environmental quality) for a single generation, but does not act to internalize the intergenerational externality imposed by the current generation on future generations. However, the long-lived government can design a tax transfer scheme in which short-lived agents receive the full benefit of their taxes on environmental quality and bear the total cost of their consumption. "The long-lived government can divide net output; between consumption by the old and taxes by the young to achieve a constant level of environmental quality" (John *et al*, 1995).

Lopez (1994) pays attention to the form of the preference function; if preferences are homothetic, growth will increase pollution or degradation[7]. On the other hand, if preferences are non-homothetic, the effect of growth on pollution depends, on the relative degree of curvature of

[7] Homothetic preferences mean that, in the same period, consumers with different incomes but facing the same prices will demand goods in the same proportions.

the utility function in income (let this be α), and the elasticity of substitution in production between polluting and non-polluting inputs (let this be σ). α shows how the marginal utility of income declines as income expands. "Economic growth increases the value of the environment for consumers. If this increased value is manifested in the market, firms will have to pay an increasing price for pollution" (Lopez, 1994.P.171). A higher σ implies that, it is less costly to reduce pollution by substituting it for conventional factors. A higher α implies consumers are willing to give up a relatively grater additional income as they become rich in order to buy a better environment. Thus, a higher σ and α causes pollution to decline as income increases.

Another interesting thing in the theoretical explanation of the EKC is the incorporation of corruption and rent-seeking behavior of government officials. In their model Lopez and Mitra (2000), assumes that the goal of the government is to maximize a function of the following type; ($G = (1 - \alpha)\pi + \alpha c$)[8], which depends on the probability of being re-elected and rents. They consider both the cooperative and non-cooperative interaction between the government and firms and summarize their result in the following two propositions.

> Proposition1. *If corruption takes the form of cooperative government-private sector interactions, then (a) pollution levels will be above the socially optimal levels for any level of income; (b) an inverted-U-shaped relationship between income and pollution will exist; (c) the turning point of the inverted U-shaped curve will occur at higher per capita income (and higher pollution level) than in the socially optimal equilibrium (P.145).*
>
> Proposition2. *If government corruption takes the form of a non-cooperative Stackelberg interaction between the government and the firm, with the latter as a leader, and payment functions are linear in output, then: (a) pollution is always above the social optimum for any level of per capita income; (b) a turning point in the pollution-per capita income relationship always exists as long as a turning point exists in the socially optimal pollution-income relationship, but such a point*

[8] π is the probability of being re-elected, c the lobby payments or rents accruing to the government, α is a coefficient associated with the degree of the corruptibility of the government.

is likely to occur at a higher per capita income (and higher pollution level) than the socially optimal one (P.147).

2.1.2. The scale, composition, and technique effect

Grossman (1995) provides an intuitive explanation for the growth-environment relationship by decomposing the effect of economic growth on the environment into scale, composition and technique effects. Here is Grossman's explanation: let $\boldsymbol{Y_t}$ represent the scale of economic activity (GDP) of a country at time $\boldsymbol{t}$, $\boldsymbol{s_{it}}$, be the share of output of sector *i*, and α_{it} be the amount of waste or pollution generated per unit of output in sector *i*. then, total emission of some pollutants at time *t* is given by;

$$\boldsymbol{E_y = \sum_i \alpha_{it} s_{it} Y_t} \tag{2.11}$$

Over time emission will evolve according to

$$\boldsymbol{\widehat{E} = \widehat{Y} + \sum_i \gamma_i \widehat{s}_i + \sum_i \gamma_i \widehat{\alpha}_i} \tag{2.12}$$

Whereγ_i, is the share of the total amount of the pollutant generated by sector *i*, and a 'hat' over a variable indicates a rate of change.

When we look at equation (2.12), the first term on the right hand side represents the scale effect; "all else equal an increase in output means an equi-proportionate increase in pollution" (Grossman, 1995). However, the second term (the composition effect) and the third term (the technique effect); will violate the all else equal condition (de Bruyn, 1997). Emission may fall if the share of relatively cleaner economic activities increase, and if technological progress, market induced substitution or government regulation cause less-polluting technologies replace dirtier ones (Grossman, 1995; de Bruyn, 1997; Ekins, 1997).

That is, the pollution path will curve down if the composition and technique effects offset the scale effect as per capita income increases.

The composition and technique effects may include the following things as specified by Ekins (1997).

a. **Composition (structural change) effect:** shift in production and/or consumption patterns towards existing or new sectors or industries that are less environmentally damaging.
b. **Technique (technological) effect:** more efficient use of inputs, substitution of less for more environmentally intensive inputs, less generation of wastes, transformation of wastes to less environmentally harmful forms, containment or recycling of wastes, a shift within a sector towards new, less environmentally harmful products or processes.

2.1.3. International Trade

Trade is another force which gives rise to the EKC; "when income increases, countries increase their import of pollution-intensive goods-in essence exporting pollution" (McConnell, 1997). This is due to the fact that as income rise people's demand for environmental quality increases and governments start to internalize external effects by appropriate legislations (Grossman and Krueger, 1995); which might result in displacement of dirty industries from high-income to low-income countries (Ekins, 1997; deBruyn, 1997). Further, Xu and Song (2000) explain the effect of environmental regulation through 'trade in embodied environmental factor services'. Countries with stringent environmental regulation will have more embodied environmental factor services in their imports than in their exports, while the opposite pattern will hold for countries with less stringent environmental regulations (Xu and Song, 2000).

Lopez (1994) considers the effect of trade liberalization on the environment in a typical developing country. He assumes that the economy is small and open. The country produces two tradable outputs; an agricultural good which is exportable and a manufactured good which is a substitute for imports. It is assumed that production of the manufacturing is more intensive in pollution input than agriculture. Furthermore, the model assumes neither the production nor the consumption pollution externalities are internalized.

The revenue function for this economy is thus;

$$R = R(P_A, 1 + m, f(K, L), x_1) \quad (2.13)$$

Where the world price of the manufactured good is normalized to 1, m is the *ad valorem* tariff rate, $(1 + m)$ is its domestic price (domestic price of the manufactured good), P_A is price of the agricultural good, and x_1 is production pollution.

Define $x_2 = x_2(c_2)$, with $x'_2 > 0$ as consumption pollution; consumption of durable manufactured goods like operation of cars, refrigerators, air conditioners are important sources of consumption pollution (Lopez, 1994). Thus, the consumption pollution focuses on pollution from industrial goods.

A decrease in 'm' increases the consumption of the manufactured good. Thus, consumption pollution will increase. "Lowering protection reduces production generated pollution but at the same time increases consumer-generated pollution. The strength of the production effect will depend on the supply elasticity of the manufactured good and on the pollution intensiveness of the manufacturing production" (Lopez, 1994.P.180).

2.1.4. Environmental Policy

The EKC hypothesis states that higher income is associated with improved environmental conditions. However, in the process of economic growth “the transition period may be long and painful during which serious environmental deteriorations can occur” (Beckerman, 1992). Thus, we need environmental protection measures (or environmental policy). Countries may take different environmental protection measures and increase their environment protection expenditure. However, most of the time, environmental protection expenditures are responses to damages that have already occurred and not meant to prevent the damage; they are rather spent to repair the damage that occurred in the process of economic growth (Simonis, 1989). Hence, it is better to shift technical solutions for environmental problems from controlling or end of –pipe technology towards low emission and/or integrated technology (Simonis, 1989). This will work if environmental policy is a national or local concern and not for policies with international implications like climate change (Beckerman, 1992).

Developing and developed countries are different in their policy priorities with regard to the importance they attach to economic growth relative to the environment and within the environment, the relative importance they attach to its different components (Beckerman, 1992). In this case, if the environmental policy is to reduce the emission of greenhouse gases, then first developing countries may not recognize that climate change imposes a sufficient threat to devote their resources in order to reduce their emission. Second even if developed countries have the potential to take effective measures to reduce global warming, there is less incentive to do so because the share of agriculture in those economies is small and hence the impact of global warming on their economies is relatively insignificant (Beckerman, 1992).

Currently different international agreements (like the Kyoto protocol, the United Nations Framework convention on climate change (UNFCCC)) have been signed by countries in order to reduce the adverse effect of climate change and to limit the average increase of the global temperature below 2℃ by the end of this century (by 2100). The intended nationally determine contribution (INDC)[9] is one step in this attempt in which countries submit their INDC to UNFCCC to mitigate greenhouse gas emission (GHG) in different sectors. Ethiopia is one of those countries who submit the INDCs to UNFCCC disaggregated by different sectors. The Ethiopian INDC covers the three major greenhouse gases (CO_2, CH_4, N_2O) to be mitigated in different sectors (IBRD, 2016). The following Table provides us the disaggregated information.

Table 2.1**:** Mitigation target of Ethiopia for GHGs (CO_2, CH_4, N_2O) to be achieved by 2030 in different sectors

Mitigation actions and policies	**Targets**
Energy	-19 MtCO_2e by 2030 due to export of electric power
Transport	-10 MtCO_2e by 2030
Agriculture	-90 MtCO_2e by 2030
LULUCF/Forestry	-130 MtCO_2e by 2030
Industries	-20 MtCO_2e by 2030
Buildings	-5 MtCO_2e by 2030

Source: IBRD, 2016

Ethiopia intends to limit net GHG emissions in 2030 to 145 MtCO_2e which constitutes a reduction of 255 MtCO_2e or 64 % from the Business as Usual (BAU)[10] emissions Scenario (FDRE, 2015). In the BAU scenario, it is predicted that GHG emission in Ethiopia will increase from 150 MtCO_2e in 2010 to 400 MtCO_2e by 2030 (FDRE). The 64 % intended reduction in

[9] INDCs are submissions by parties which identify actions each national government intends to take under the UNFCCC climate change (UNEP, 2015)

[10] Business-as-Usual (BAU) is a scenario that describes future GHG emission level in the absence of additional mitigation efforts and policies (UNEP, 2015).

GHG emissions does not constitute the 19 MtCO_2e reductions due to the export of electric power to neighboring countries. Unfortunately, the Ethiopian INDCs are conditional INDCs. It means that the achievements of these mitigation targets in different sectors are conditional on the support of the international community. It might be financial, technical or any capacity building support (IBRD, 2016).

2.2. Empirical Literature

Many empirical studies have been conducted to examine the relationship between economic growth and environmental quality. These studies aim to test the environmental Kuznets curve (EKC) hypothesis though might be different in the type of data, model specification and explanatory variables included, environmental indicators they took as dependent variable, and estimation techniques. While some of them accept the EKC hypothesis, some others reject it.

By using cross-section data from both developing and developed countries and ordinary-least square technique, Panayotou (1993) had tested the EKC hypothesis. Deforestation, sulfur dioxide(SO_2), suspended particulate matter(PM_{10}), and oxides of nitrogen (NO_X) are the environmental indicators in the work of Panayotou. He confirms the existence of EKC for all the environmental indicators considered in his study. Selden and Song (1994) investigates the inverted-U relationship between pollution and economic development using cross-national panel data for sulfur dioxide (SO_2), suspended particulate matter (PM_{10}), oxides of nitrogen (NO_X), and carbon monoxide (CO). They estimate both the fixed-effect and random-effect models and found that per capita emission of all four pollutants exhibit inverted-U relationship with per capita income.

Grossman and Krueger (1995) by using the GEMS air and water pollution data, estimates the reduced-form relationship between per capita income and various environmental indicators. The model specification of this study is a little bit different in that, it includes the average value of three years lagged per capita incomes in its cubic form as explanatory variable. Urban air pollution, the state of the oxygen regime in river basins, fecal contamination of river basins, and contamination of river basins by heavy metals are the environmental indicators considered in this study. Using random-effects model and generalized least squares (GLS) technique, the study confirms EKC for all environmental indicators considered in the study.

In an attempt to analyze the evidence of EKC for water pollution for developing and developed countries, Shahpouri *et al* (2016) uses a panel data of 54 countries grouped[11] into 5. They took Biochemical Oxygen Demand (BOD) as a proxy for water pollution. In addition to per capita income and square of it, capital-labor ratio (as a proxy for the composition effect) and trade openness were taken as explanatory variables. The study applied Generalized Least Squares (GLS) and confirms the inverted-U relationship between income and water pollution for all groups of countries, except for developed countries with low-income.

Effiong and Oisaozoje (2016) to identify a definite shape of the income-pollution relationship, applies a flexible semi-parametric panel fixed effects technique for a sample of 49 African countries including Ethiopia. The dependent variable are CO_2 and PM_{10}. The result shows that, while theCO_2-income relationship is monotonically increasing, the PM_{10}-income relationship is monotonically decreasing. In a similar way Cole and his associates (Cole et al, 1997) examines the relationship between income and a wide range of environmental indicators by using cross-

[11] The study categorizes the countries in to developed countries, developing countries, developed countries with low income, developed countries with high income and coastal countries. In this study Ethiopia is included under the list of developing countries.

country panel data set. The empirical estimation of this study suggests that EKC exists only for local air pollutants (or environmental indicators). For those environmental indicators with more global or indirect effect on the environment, "the pollution curve rises monotonically with income or else have high turning points with large standard errors".

Jalil and Mahmud (2009) and Rabbi *et al* (2015) with the same model specification (same environmental indicator and explanatory variables) examine the income-pollution relationship for China and Bangladesh respectively. While the time series data for China runs from 1975-2005, it is from 1971-2012 for Bangladesh. In these two studies the environmental indicator is CO_2 emission; the quadratic form of income per capita, energy use and trade openness are incorporated as explanatory variables for CO_2 emission. The study for China employs autoregressive distribution lag model (ARDL) and error correction model (ECM) techniques and arrived at an inverted-U shaped relationship between CO_2 emission and income per capita. On the other hand, the study of Rabbi and his associates (Rabbi et al, 2015) employs Johansen co-integration and vector error correction mechanisms (VECM) and found that there is an inverted-shaped relationship between CO_2 emission and per capita income.

Another study by Arouri *et al* (2014) examines the income-pollution relationship for Thailand over the period 1971-2010. In its model specification, this study is different from the above two studies only for its incorporation of urban population as explanatory variable. The study employs ARDL bound test approach, unrestricted error correction model (UECM), and vector error correction model (VECM) to examine co-integration among the series. The empirical estimation result shows the presence of EKC in Thailand for CO_2 emissions.

Akbostanci *et al* (2009) examines the relationship between income and the environment in Turkey. They employ both time series and panel data models. The panel data model is for Turkish provinces. In the time series model the environmental indicator is CO_2 emission. In this model they specified CO_2 emission as a cubic function of per capita income and there is no other explanatory variable included. By applying augmented Dickey-Fuller (ADF) test for stationarity and Johansen co-integration technique, the study founds an –N shaped relationship between CO_2 emission and income per capita. For the second model (the panel data model) the environmental indicators are sulfur dioxide (SO_2) and suspended particulate matter(PM_{10}). In addition to the cubic form of per capita income, population density measure is included in the model. The same N shaped relationship found for both SO_2 and PM_{10}.

Some studies pay attention to the importance of institutions and political rights in explaining the relationship between income and environmental quality. Bhattarai and Hammig (2001) take a sample of 66 countries from America, Africa and Asia in order to examine the relationship between income and deforestation. In this study in addition to the quadratic form of income per capita; political institutions, technological change, macroeconomic and policy related variables and population are included as explanatory variables. The study estimates fixed-effects model by GLS and found an inverted-U shaped relationship between income and deforestation in all the three continents. This study suggests that, "underlying institutional factors are relatively more important for explaining the tropical deforestation process than other frequently cited factors like population and macroeconomic conditions"[12].

[12] In this study political institution is the sum of political rights and civil liberties indices (Bhattarai and Hammig, 2001).

By taking a cross- state panel data of 1999 and 2005 in Mexico and sulfur dioxide (SO_2) as environmental quality indicator; Kochi and Lopez (2013) estimates the income-pollution relationship for Mexico. They divide the sources of SO_2 emission into point, area, and mobile sources[13]. The industrial sector share in total GDP, the quality of institutions, Gini index, foreign direct investment (FDI), and the quadratic form of per capita income are included as explanatory variables. The empirical evidence in this study shows that, the quality of institutions significantly affects the level of some types of pollution. In particular the mobile-oriented pollution data indicates that, the higher the level of corruption, the higher the pollution level. The study found that there is an inverted-U shaped relationship between per capita income and SO_2 emission for all the point, area, and mobile sources.

Another two studies which stress the importance of institutional quality, and political rights and civil liberties in explain the income- pollution relationship are conducted by Sahli and Rejeb (2015); and Torras and Boyce (1998). The study by Sahli and Rejeb (2015) aims to estimate the effect of corruption on per capita emission by taking a balanced panel date from 21 countries in the Mena region (including Ethiopia) over the period 1996-2013. In this study the dependent variable is carbon dioxide (CO_2) emission; the quadratic form of income per capita, corruption, trade openness, and industrial share of GDP are explanatory variables. They found an EKC for CO_2 emission and the empirical test shows a positive direct effect of corruption on per capita CO_2 emission and a negative indirect effect on per capita income. On the other hand, Torras and Boyce (1998) use GEMS air and water pollution data spanning 1971-1991 for about seven air and water pollution variables. The air pollution data contain observations from 18-52 cities in

[13] Point sources are large industrial sources such as manufacturing sources, area sources are various smaller scale production activities such as small business, and the mobile sources are defined as automobiles (Kochi and Lopez, 2013).

19-42 countries. The water pollution data contain observations from 287 stations in 58 countries. For low- income countries they found that literacy and rights (political rights and civil liberties) are strong predictors of pollution levels.

In West Germany and the Netherlands commercial (SO_2) have fallen since 1970s despite the growth of income de Bruyn (1997). That is, according to equation (2.12) the reduction of SO_2 emission due to the composition (structural) and technological effect dominates the scale effect. In order to test the relative contribution of each effect, de Bruyn (1997) have performed a decomposition analysis for commercial SO_2 emission between 1980 and 1990 for the two countries. The decomposition result shows that the major part of the reduction in commercial SO_2 emission is due to technological change both for West Germany and the Netherlands. The effect of the structural change is even positive for the Netherlands. “Environmental policy may have been quite successful in reducing SO_2 emission in the two countries”. Provided that these countries are developed and if environmental policy is strict in developed countries; the technological effect due to environmental policy is line with the EKC hypothesis.

There are also empirical studies conducted to examine the income-pollution relationship in Ethiopia. Endeg (2015) by taking time series data spanning 1969/70 to 2010/2011 and employing vector error correction model (VECM) examines the relationship between economic growth and environmental quality in Ethiopia. In this study the environmental quality indicators is CO_2 emission. The quadratic form of income per capita and trade openness are incorporated as explanatory variables. The empirical result from the econometrics procedures shows the existence of EKC for CO_2 emission in Ethiopia over the sample period (1969/70-2010/11). Lamessa (2015) also examines the income-pollution relationship in Ethiopia with particular emphasis for the impact of trade liberalization on air pollution. Results from Johansen co-integration and error correction model technique reject the existence of EKC for CO_2 emission in Ethiopia over the sample period 1981-2010.

However, these two studies are short of capturing the effect of sectoral output composition (structural change) of the economy. In addition to this, both of these studies have tried to capture the effect of international trade on CO_2 emission by trade openness (or by the ratio of the sum of export and import to GDP). But this variable did not show what kinds of products the country imports and exports. Thus, this study adds on the existed literature about the relationship between CO_2 emission and per capita income in Ethiopia by capturing the effect of structural change in the output composition of the economy; and by representing international trade by the ratio of manufacturing export to manufacturing GDP and the ratio of manufacturing import to manufacturing GDP separately.

Chapter Three

Data and Methodology

3.1. The Data and its Sources

In this study we have used secondary data spanning from 1981 to 2013. The selection of the time period is dependent on the availability of data. In this study the dependent variable is CO_2 emission. Gross domestic product (GDP) per capita and square of it, industrial share of GDP, the ratio manufacturing export to manufacturing GDP, and the ratio of manufacturing import to manufacturing GDP are independent variables[14].

The data on CO_2 emission is from the Carbon Dioxide Information Analysis Center (CDIAC), GDP per capita, the industrial share of GDP, manufacturing GDP, total export, total import, share of manufacturing export, and the share of manufacturing import data are taken from World Development Indicators (WDI) of the 2016 world development report database.

3.2. The Empirical Model

In the Environmental Kuznets curve (EKC) analysis, the environmental quality indicator is usually expressed as a quadratic function. Per capita GDP and squared GDP per capita are common explanatory variables in the econometrics studies of the income-environment relationship (Suri and Chapman, 1998). On the one hand, the GDP variable captures scale effect of economic activity; *ceteris paribus*, the larger the scale of economic activity the higher the

[14] The ratio of manufacturing export to manufacturing GDP= $X * X_m/GDP_m$ and the ratio of manufacturing import to manufacturing GDP=$M * M_m/GDP_m$. Where X is merchandise export in a specific year, X_m the share of manufacturing export in total export, GDP_m is the manufacturing GDP of the country in a specific fiscal year, M is merchandise import and M_m is the share of manufacturing import in total import.

level of pollution. On the other hand, squared per capita GDP is expected to capture the effects of structural change in the output composition of the economy and environmental awareness and regulations (Suri and Chapman, 1998). Following Panayotou (1997), in case of pollution, the output share of the industry sector represents the effect of the structure of the economy and expected to have a positive relationship with environmental degradation.

International trade affects the environment in two respects; while export increases environmental degradation by raising the scale of economic activity, the environment might be improved by the composition and technique effects associated with international trade. Most Studies have tried to capture the effect of international trade by trade openness (the ratio of the sum of exports and imports to GDP), but it fails to show the impact of the actual movements of goods between countries that embody pollution (Suri and Chapman, 1998). Suri and Chapman (1998), and Agras and Chapman (1999) incorporates the ratio of manufacturing export to manufacturing GDP and the ratio of manufacturing import to manufacturing GDP as separate variables in order to capture the effect of international trade on the environment. Following Panayotou (1997), Suri and Chapman (1998), and Agras and Chapman (1999), the growth- environment relationship can be described by quadratic function of the form

$$E_t = f(GDP_c, GDP^2{}_c, Z_i) \tag{3.1}$$

Where E_t is the environmental indicator, the first two terms in the bracket are income per capita and squared per capita income, and Z_i incorporates other explanatory variables (in our case it includes the ratio of manufacturing export to manufacturing GDP, the ratio of manufacturing import to manufacturing GDP, and the industrial share of GDP). Specifically equation (3.1) takes the following functional form

$$CO_{2t} = \beta_0 + \beta_1 GDP_{Ct} + \beta_2 GDP_{Ct}^2 + \beta_3 GDP_{INDUt} + \beta_4 MNFG_{Xt} + \beta_5 MNFG_{Mt} + \varepsilon_t \qquad (3.2)$$

Where CO_{2t} is metric tons of per capita carbon dioxide emission at time t, GDP_{Ct} per capita income at time t, GDP_{INDUt} industrial share of GDP at time t, $MNFG_{Xt}$ the ratio of manufacturing export to manufacturing GDP at time t, $MNFG_{Mt}$ the ratio of manufacturing import to manufacturing GDP at time t, ε_t is the stochastic disturbance term, and the β's are parameters to be estimated from the econometrics procedure.

Model (3.2) provides us several forms of growth- environment relationship for different values of the coefficients β_1 and β_2 (Dinda, 2004).

a) If $\beta_1 = \beta_2 = 0$, it indicates that there is no relationship between per capita GDP and CO_2 emission
b) If $\beta_1 > 0 and\ \beta_2 = 0$, then there is an increasing relationship (or CO_2 emission is an increasing function of per capita income).
c) $\beta_1 < 0\ and\ \beta_2 = 0$, shows a decreasing relationship (or CO_2 emission is a decreasing function of income per capita).
d) $\beta_1 > 0\ and\ \beta_2 < 0$, represents an inverted-U shaped relationship between income and CO_2 emission (or the EKC curve).
e) $\beta_1 < 0\ and\ \beta_2 > 0$ represents –U- shaped relationship

If (d) holds, then the turning point to the EKC (the level of per capita income at which CO_2 emission starts to diminish) can be calculated as; $GDP_c = -\frac{\beta_1}{2\beta_2}$. To come up with this result, simply take the first partial derivative of (3.2) with respect to GDP_c and set it equal to zero, and then solve for GDP_c.

3.2.1. Description of variables

The environmental quality indicator is captured by CO_2 emission which is expressed in metric tons per capita.

(A). industrial share of GDP (GDP_{INDUt}): it is defined as the GDP share of mining, manufacturing, construction, electricity, water, and gas in total GDP. This variable is expected to capture the effect of sectoral output composition of the economy on the environment.

(B). the ratio of manufacturing export to manufacturing GDP ($MNFG_{Xt}$): the merchandise export shows the F.O.B value of goods provided to the rest of the world valued in current U.S dollars. Manufactures export is percentage share merchandise export which comprises chemicals, basic manufactures, machinery and transport equipment, and miscellaneous manufactured goods excluding non-ferrous metals. The ratio of manufacturing export to manufacturing GDP is calculated as provided in foot note 14.

C). the ratio of manufacturing import to manufacturing GDP ($MNFG_{Mt}$): the merchandise import shows the C.I.F value of goods received from the rest of the world valued in current U.S dollars. It comprises what we have mentioned in section **(B).** The manufacturing import to manufacturing GDP ratio is calculated based on foot note 14.

(D). GDP per capita (GDP_{Ct}): it is gross domestic product (GDP) divided by midyear population. Here GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. The data are in current U.S dollars. It captures the scale effect of an increase in output on the environment.

3.3. **The Econometrics Procedure**

Stationarity: in building dynamic econometric models the first step entails a detailed analysis of the characteristics of the individual time series variables involved. This is because the specific characteristics of the series may be an integral part of the relationship of interest, or they may reflect features that are not of interest for the relationship under study but may still be of importance for the statistical procedures used in analyzing a given system of variables (Lutkepohl and Kratzig, 2004). Therefore, understanding of the individual time series properties is important before a set of series is modeled jointly. Stationarity is a statistical characteristic of a time series such as its mean and variance. If both the mean and variance of a time series are constant over time (does not depend on time), the series is a stationary process (Hamilton, 1994). For instance given the following first order autoregressive process (AR (1));

$$Y_t = c + \emptyset Y_{t-1} + \varepsilon_t \quad (3.3)$$

Where ε_t is white noise $(E(\varepsilon_t) = 0, E(\varepsilon_t^2) = \delta^2)\ and\ E(\varepsilon_t, \varepsilon_{t-1}) = 0$

Take expectations of both sides of (3.3)

$E(Y_t) = c + \emptyset E(Y_{t-1}) + E(\varepsilon_t)$, provided that the mean of the process does not depend on time and the error term has a mean of zero and let μ is $E(Y_t)$, then

$$\mu = c + \emptyset\mu \Rightarrow \mu = c/(1-\emptyset) \quad (3.4)$$

Substituting (3.4) into (3.3) for c

$$Y_t = \mu(1-\emptyset) + \emptyset Y_{t-1} + \varepsilon_t$$

$$(Y_{t-1} - \mu) = \emptyset(Y_{t-1} - \mu) + \varepsilon_t \quad (3.5)$$

Square both sides of (3.5) and take expectations

$$E(Y_t - \mu)^2 = \emptyset^2 E(Y_{t-1} - \mu)^2 + 2\emptyset E[(Y_{t-1} - \mu)\varepsilon_t] + E(\varepsilon_t^2) \quad (3.6)$$

Let, $E(Y_t - \mu)^2$ is γ_0; the second term on the right hand side of (3.6) is zero since ε_t is uncorrelated with its lagged values, assuming co-variance stationary the first term on the right hand side will be $\emptyset^2\gamma_0$ and the third term is δ^2. Hence (3.6) can be written as

$$\gamma_0 = \emptyset^2\gamma_0 + \delta^2 \Rightarrow \gamma_0 = \delta^2/(1 - \emptyset^2) \quad (3.7)$$

Both the mean and variance of the first-order autoregressive process (AR (1)) given by equation (3.3) is independent of time, hence stationary. A time series generated by a stationary stochastic process must fluctuate around a constant mean and does not have a trend (Lutkepohl and Kratzig, 2004).

If the coefficient of the lagged value of Y_t in equation (3.3) is unity ($\emptyset = 1$)-the so called unit root, then the stochastic process (3.3) will be reduced to

$$Y_t = c + Y_{t-1} + \varepsilon_t \quad (3.8)$$

Taking variance on both sides of (3.6), $V(Y_t) = V(Y_{t-1}) + \delta^2$, which has no solution for the variance of the process consistent with stationarity, unless $\delta^2 = 0$. Thus we have to conduct unit root test to check for stationarity of the stochastic process. This study applies the augmented Dickey-Fuller method to test for unit root. By this method the null hypothesis of unit root is tested against the alternative of stationarity. That is according to the stochastic process in (3.3) the null and alternative hypotheses of unit root test are:

$$H_0: \emptyset = 1, unit\ root$$

$$H_1: \emptyset < 1, stationary$$

Co-integration: if each element of a vector of time series X_t achieves stationarity after first differencing and if there exists a combination of $\alpha' X_t$ which is stationary, then the series X_t are said to be co-integrated with a co-integrating vector α (Engle and Granger, 1987). Furthermore, Engle and Granger (1987) stress the importance of differencing in time series by stating that, "commonly economic series must be differenced before the assumption of stationarity can be presumed to hold". A time series process X_t which achieves stationarity after first differencing is said to be integrated of order one ($X_t \sim I(1)$). To be clear, suppose that $Y_t \sim I(1)$ and $X_t \sim I(1)$, then Y_t and X_t are said to be co-integrated if there exists a β such that $Y_t - \beta X_t$ is $I(0)$. If we regresses a non-stationary variable Y_t on another non-stationary variable X_t, it may lead to a so-called spurious regression in which the true value of the coefficient of X_t, say β, is actually zero (Maddala, 1992; Verbeek, 2004). However, the use of non-stationary variables does not necessarily results in invalid estimators; provided that if there exists a linear combination of these non-stationary ($I(1)$) variables which is stationary (Verbeek, 2004). This co-integration shows the existence of long-run relationship between Y_t and X_t. In general, knowing the number of co-integrating relations among time series variables is important as it shows the existence of a long-run relationship between them. This can be done through different testing procedures for co-integration.

We have applied the Johansen co-integration test procedure to decide on the number of co-integrating relationships. In this method there are two different tests; the maximum eigenvalue test and the trace test. The maximum eigenvalue statistics tests the null hypothesis of r co-integrating relations against the alternative of $r+1$ co-integrating relations for $r = 0, 1, \ldots\ldots, n-1$ where n is the number of variables. Mathematically the maximum-eigenvalue statistics can be computed as

$$\lambda_{max}(r_0) = -T\log(1-\lambda_{r_{o+1}}) \qquad (3.9)$$

On the other hand, the Trace statistics tests the null hypothesis of r co-integrating relations against the alternative of n co-integrating relations and it can be computed as;

$$\lambda_{trace}(r_0) = -T\sum_{j=r_0+1}^{k}\log(1-\hat{\lambda}_j) \qquad (3.10)$$

Vector Error Correction Model (VECM): the differencing operation to achieve stationarity works by eliminating the long-run relationship between the variables. If both Y_t and X_t are $I(1)$ but have a long-run relationship (if they are co-integrated), there must be some force which pulls the equilibrium error back towards zero. This can be done by the error correction model (ECM) or equilibrium correction mechanisms (Verbeek, 2004). The ECM describes how Y_t and X_t behaves in the short-run consistent with a long-run co-integrating relationship. That is, it links the long-run equilibrium relationship implied by co-integration with the short-run adjustment mechanism that describes how the variables react when they move out of long-run equilibrium.

If an $N\ x\ 1$ stochastic process X_t is co-integrated with co-integrating rank r, then there exists an error correction representation with $Z_t = \alpha' X_t$, an $r\ x\ 1$ vector of stationary random variables. In a two variables case Y_t and X_t both $I(1)$ and $Z_t = Y_t - \beta X_t \sim I(0)$, then error correction representation (or ECM) of it can be written as

$$\Delta Y_t = \beta\Delta X_t - \gamma(Y_{t-1} - \beta X_{t-1}) + \varepsilon_t \qquad (3.11)$$

It says that change in Y_t is due to current period change in X_t plus last periods disequilibrium (or the error correction term).

In a multivariable (or for a set of K time series variables) case, their dynamic interaction can be represented by vector autoregressive (VAR) model of the following form

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \tag{3.12}$$

Where A_i's are $(K \; x \; K)$ coefficient matrices and $u_t = (u_{1t}, \dots \dots ., u_{kt})'$ is an unobservable white noise error term.

The process is stable if

$$det\left(I_k - A_1 z^1 - \cdots - A_p z^p\right) \neq 0 for \; |z| \leq 1 \tag{3.13}$$

that is, the polynomial defined by the determinant of the autoregressive operator has no roots in and on the complex unit circle. If the polynomial in (3.11) has a unit root (or its determinant is zero for $z = 1$), then some or all of the variables are integrated. Assume the variables are at most integrated of order one ($I(1)$). If there are linear combination of them that are $I(0)$, then they are co-integrated. If co-integration relations are present in a system of variables, then it is convenient to apply vector error correction models (VECMs) or vector equilibrium correction models (Lutkepohl and Kratzig, 2004). The VECM form of (3.12) is

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t \tag{3.14}$$

It is a more convenient model setup for co-integration analysis. This is because the vector autoregressive (VAR) representation of a co-integrated system omits the error correction term (Engle and Granger, 1987). Here $\Pi = -(I_K - A_1 - \cdots - A_p)$ and $\Gamma_i = -(A_{i+1} + \cdots + A_p)$ for

$i = 1, \dots, p-1$. The Γ_is are short-run or short term parameters, and Πy_{t-1} is the long-run or long term part.

Chapter Four

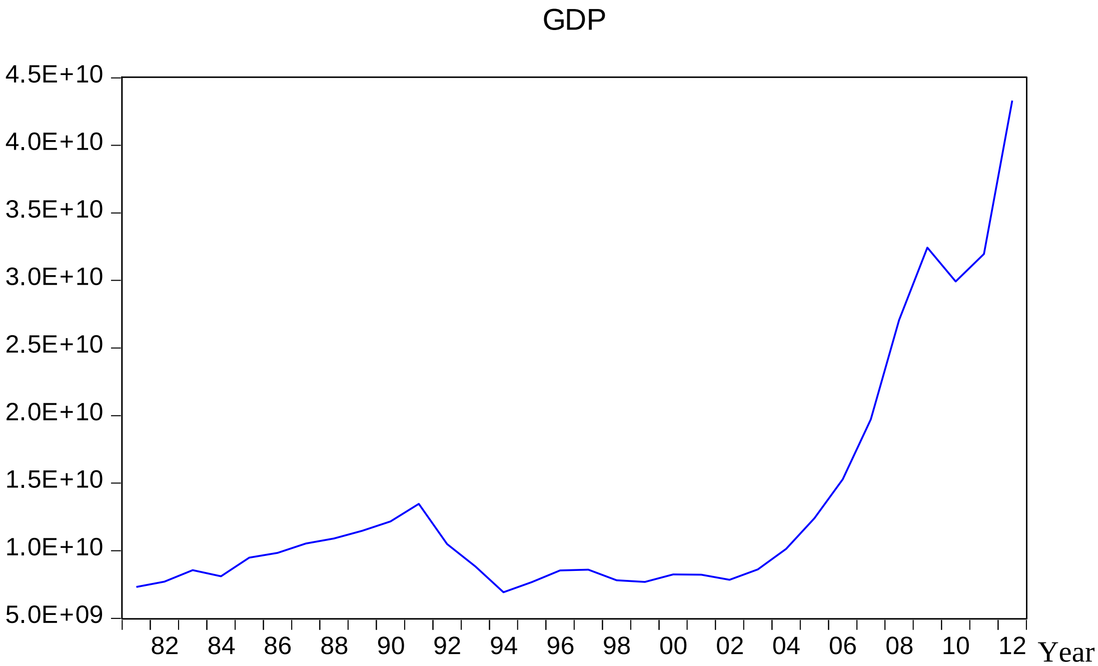
Data Analysis and Presentation

4.1. Descriptive Analysis

The decomposition method which we have described in section 2.1.2 enables to investigate the origin of the change in emission in the process of economic development; whether the change in emission is due to the change in the structure of the economy or due to technique effects. However, unavailability of sectorial based CO_2 emission and corresponding sectorial GDP data prohibits us from doing so. Even if this is the case, from the annual total greenhouse gas (GHG) emissions and GDP data, we can discuss about how the Ethiopian economy is carbon intensive.

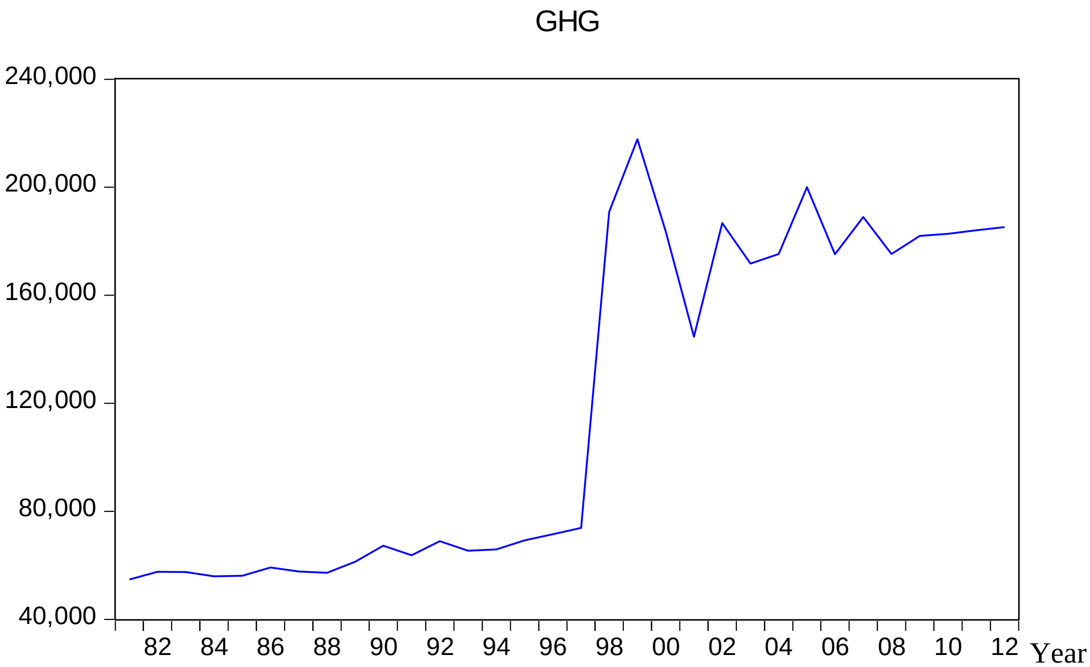
Between 1981 and 2012 GDP increases by about 491 % while the total greenhouse gas emission increases by 238%. It means that the 2012 output of the country is less carbon intensive compared to 1981. From figures 4.1 and 4.2, both GDP and GHG emission is likely to follow a more or less upward trend. That means higher output is associated with higher emission between the two periods (1981 and 2012). But it does not mean that lower output is necessarily associated with lower emission. When GDP falls between 1992 and 2002, emission followed an upward trend. That is, it increases steadily except in 2000 and 2001. This shows that an increase in GDP is not the only responsible factor for an increase in GHG emission; there might be other factors which contributes a lot for greenhouse gas emission. For instance if we ask a question of, why GHG emission does not fall between 1992 and 2002 when GDP followed a downward trend? It might be because the relative share of more polluting industries was high (output composition of the economy) or our institutions are weak to enforce environmental regulations (technique effects) which keeps greenhouse gas (GHG) emission at a higher level.

Figure 4.1: GDP trend of Ethiopia between 1981 and 2012



Source: author's representation based on data from world development indicators

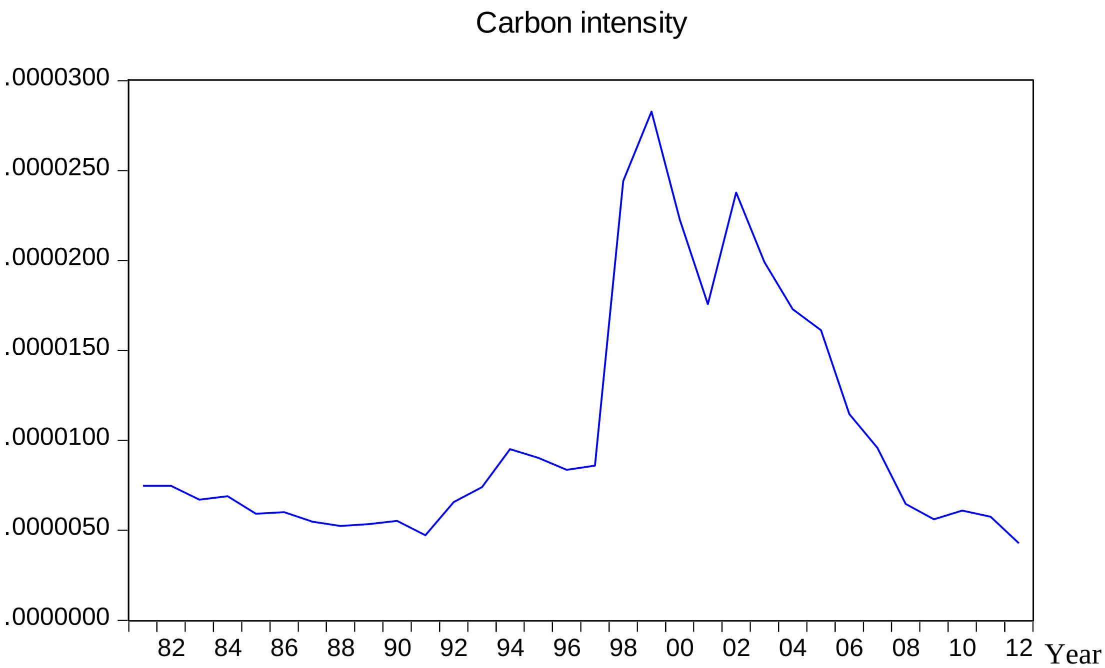
Figure 4.2: Greenhouse gas emission trend between 1981 and 2012 measured in KtCO_2 equivalent



Source: author's representation based on data from world development indicators

When we compare figure 4.1 and figure 4.3, between the period 1981 and 1991 GDP follows an upward trend while carbon intensity takes a downward trend. On the other hand when GDP decreases between 1992 and 2002, carbon intensity follows an upward trend. Finally between the period 2003 and 2012, GDP takes an upward trend and carbon intensity follows a downward trend. It means that when output is high, carbon intensity (the amount of carbon per unit of output) is low and vice-versa. This supports our justification in the previous paragraph that, 'there might be other factors other than the increase in GDP' which contributes for an increased GHG emission. This is because the inverse relationship between GDP and carbon intensity indicates that, a higher GDP is not necessarily associated with a higher GHG emission and lower GDP does not necessarily result in higher GHG emission. In addition, the inverse relationship does not indicate that higher GDP is associated with lower emission and lower GDP with higher emission; this is because from figure 4.2 we have observed that GHG emission increases over time.

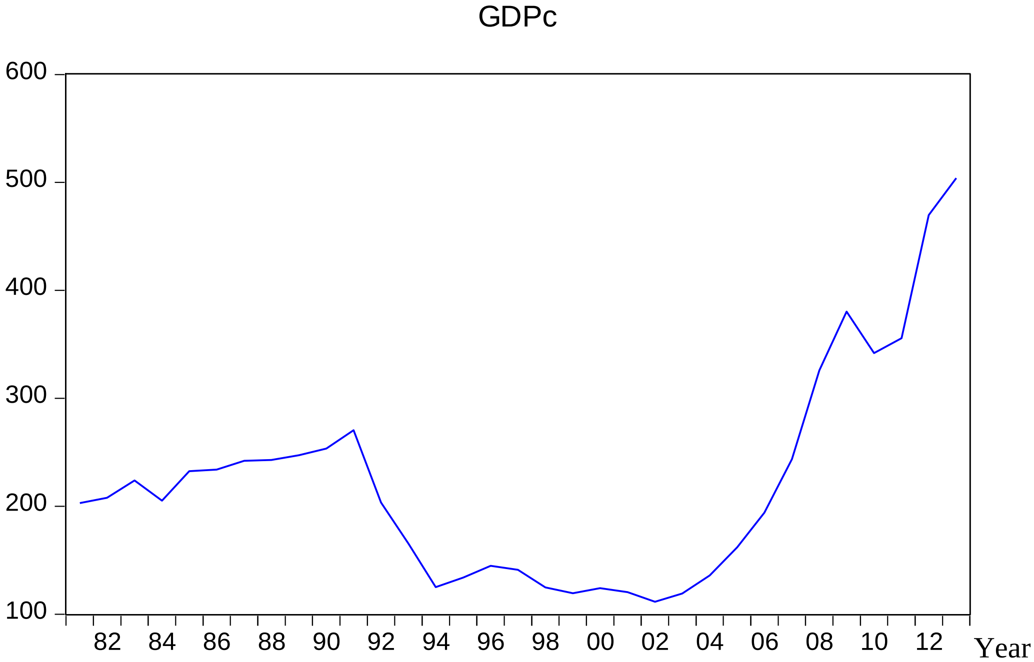
Figure 4.3: carbon intensity (greenhouse gas emission relative to GDP) between 1981 and 2012



Source: author's representation based on data from world development indicators

When we come to our specific objective (the relationship between per capita CO_2 emission and per capita GDP), an almost similar pattern as in the relationship between GDP and total GHG emission is observed.

Figure 4.4: GDP per capita between 1981 and 2013

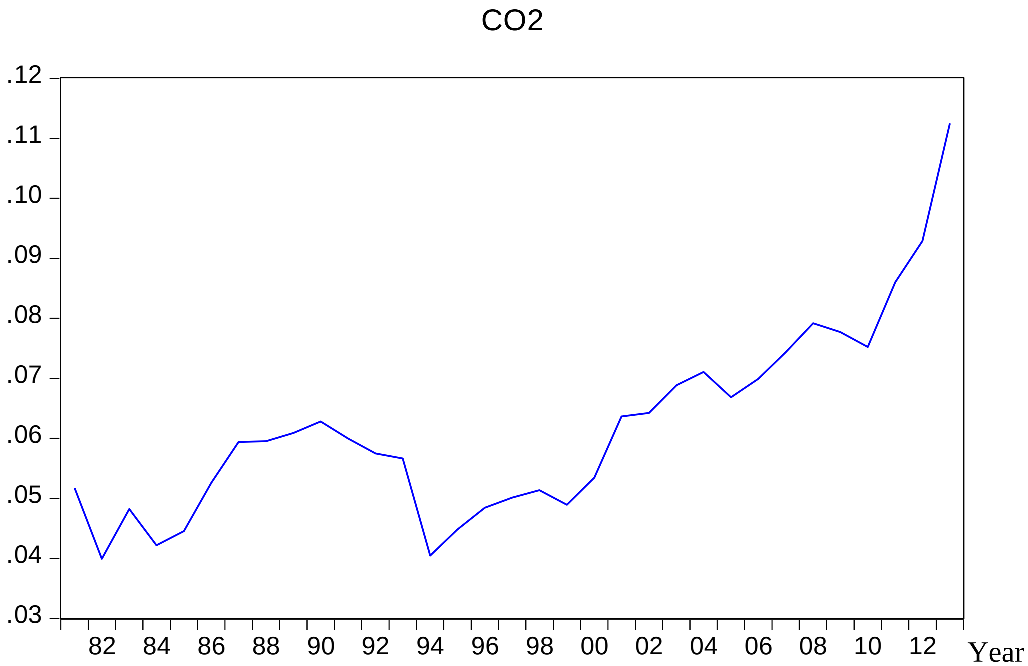


Source: author's representation based on data from World Development Indicators

Per capita income measured in current US Dollar rise starting from 1981 to 1992 and falls between 1993 and 2002, then increases starting from 2003 onwards. The corresponding CO_2 emission follows an almost increasing trend with in the sample period. In this part of the analysis what we are interested with is the relationship between per capita CO_2 emission and per capita income (GDP). Figure 4.4 and 4.6 help us to say something about this relationship.

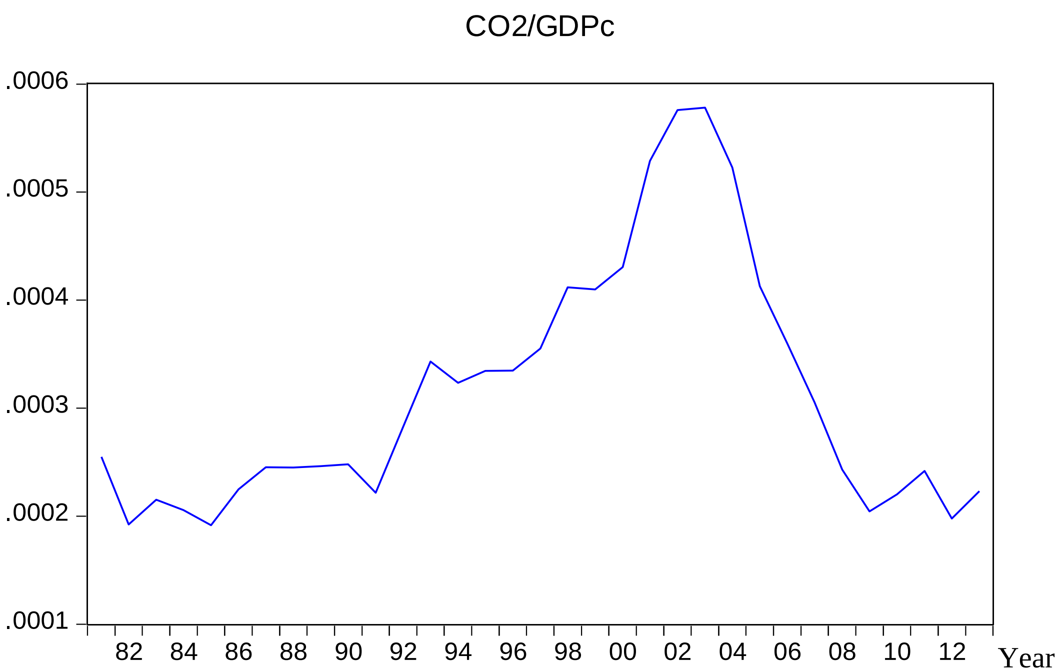
First let us compare GDP per capita and per capita CO_2 intensity between 1981 and 2002. While GDP per capita increases between 1981 and 1991 and then falls between 1992 and 2002, per capita CO_2 emission relative to GDP per capita follows an increasing trend between 1981 and 2002. The ratio of per capita CO_2 emission to GDP per capita follows a decreasing trend between 2003 and 2009 when GDP per capita rises steadily then it fluctuates. This relationship implies that even if the relative per capita CO_2 emission increases when GDP per capita rises it does not fall when GDP per capita decrease. Thus, there are factors other than the increase in income contributing for per capita CO_2 emission; like the structure of the economy (or the input and output mix of the economy) and technological factors.

Figure 4.5: per capita CO_2 emission from 1981 to 2013



Source: author's representation based on data from world development indicators

Figure 4.6: per capita CO2 emission relative to per capita GDP



Source: author's representation based on data from World development indicators

4.2. Econometric Tests

4.2.1. Stationarity test

The first step in time series data analysis is to check whether the variables has unit root or not. In this study we have implemented Augmented Dickey-Fuller (ADF) unit root test in order to determine the order of integration of the time series variables.

Table 4.1: Augmented Dickey-Fuller (ADF) unit root test

variables		At level	1st difference	Order of integration
CO_{2t}	Intercept only	-0.063509	-6.667737*	$I[1]$
	Trend and intercept	-1.831682	-6.668024*	$I[1]$
GDP_c	Intercept only	-0.733200	-3.237418**	$I[1]$
	Trend and intercept	-0.728958	-3.598826**	$I[1]$
GDP_{Ct}^2	Intercept only	-0.666825	-6.347268*	$I[1]$
	Trend and intercept	-0.922128	-6.699479*	$I[1]$
indGDP	Intercept only	-2.001662	-4.635415*	$I[1]$
	Trend and intercept	-2.223271	-4.538112*	$I[1]$
MNFGx	Intercept only	-2.213629	-6.532185*	$I[1]$
	Trend and intercept	-2.875149	-6.476596*	$I[1]$
MNFGm	Intercept only	-0.278076	-6.434747*	$I[1]$
	Trend and intercept	-2.838583	-6.522139*	$I[1]$

Note that: * and ** indicates stationarity of a time series variable at 1 % and 5 % significance level respectively.

Source: author's computation from Eviews9

As we can observe from Table 4.1, using the Augmented Dickey-Fuller unit root test, at their level, we fail to reject the null hypothesis of unit root (not stationary) of the time series variables both with intercept only and trend and intercept. Thus, at level all of the variables have unit root. When we take the first difference of each variable and conduct unit root test, we reject the null hypothesis of unit root and accept the alterative of stationarity of the series both with intercept only and trend and intercept. At first difference, all the time series variables included in this study are stationary, meaning that, they are integrated of order one ($I(1)$).

4.2.2. The Johansen Co-integration Test

From Table 4.1 all the variables included in our model are integrated of order one ($I(1)$). Given that all the variables are integrated of the same order, we can conduct Johansen co-integration test. But, before that we have to choose the maximum lag length to be included in the model based on Akaike Information Criteria (AIC) and Schwarz criteria (SIC). The lower the values of AIC or SIC, the better the model. Accordingly, a maximum lag length of two is chosen based on the lowest Akaike Information Criteria (AIC) value.

Table 4.2: lag order selection by criteria

Lag length	0	1	2
AIC value	42.86811	43.09430	41.21135*
SIC value	43.69259	45.59221	45.41494

Note that: * indicates the selected lag order by the respective criteria

As we have discussed in chapter three there are two test statistics (the trace test and the maximum eigenvalue test) in the Johansen test of co-integration. Table 4.3 and 4.4 below provide us the results of the Johansen co-integration test.

Table 4.3**:** Johansen Co-integration Test (Trace Test)

Hypothesized No. CE(s)	Eigenvalues	Trace statistic	0.05 Critical value	Prob (p-values)
None*	0.938111	190.7512	95.75366	0.0000
At most 1*	0.816903	107.2790	69.81889	0.0000
At most 2*	0.633437	56.34685	47.85613	0.0065
At most 3	0.488781	26.23927	29.79707	0.1217
At most 4	0.184123	6.110557	15.49471	0.6825
At most 5	0.000194	0.005816	3.841466	0.9385

*denotes rejection of the hypothesis at 0.05 level of significance

The first null hypothesis “None” means there is no co-integrating relationship among the variables in our system. Since the p-value is less than 5% (p=0.0000) we reject the null hypothesis of no co-integrating relationship and accept the alternative of there exists at least one co-integrating relationship among the variables. The null hypothesis of ‘At most 1’ co-integrating relationship and ‘At most 2’ co-integrating relationships are rejected in a similar manner, however, we fail to reject the null hypothesis of ‘At most 3’ co-integrating relationships among the variables in our system. Alternatively, for the first three null hypotheses (none, at most 1, and at most 2 co-integrating equations) the trace statistics is greater than their corresponding 5% critical value, so we can reject the first three null hypotheses in Table 4.3. Therefore, the trace test indicates the existence of three co-integrating vectors in our system.

Table 4.4: Johansen Co-integration test (Maximum-Eigenvalue Test)

Hypothesized No. CE(s)	Eigenvalues	Max-Eigen statistic	0.05 Critical value	Prob (p-values)
None*	0.938111	83.47223	40.07757	0.0000
At most 1*	0.816903	50.93217	33.87687	0.0002
At most 2*	0.633437	30.10758	27.58434	0.0232
At most 3	0.488781	20.12871	21.13162	0.0686
At most 4	0.184123	6.104741	14.26460	0.5998
At most 5	0.000194	0.005816	3.841466	0.9385

* denotes rejection of the hypothesis at 0.05 level

In a similar fashion as in the trace test the first three null hypotheses (None, at most 1, and at most 2 co-integrating relationships) of the maximum-eigenvalue test are rejected since the p-values are less than 5%. However, we fail to reject the null hypothesis of 'At most 3' co-integrating relationships. Thus, there are three co-integrating relationships among the variables. Both the trace and maximum-eigenvalue tests indicate that there are three co-integrating vectors in our system.

The existence of co-integration among two or more variables indicates that, there is a long-run relationship among variables in the model. The Johansen co-integration test provides us with the information of the co-integrating coefficients. From the Johansen co-integration test we have found the following co-integrating coefficients.

Table 4.5: Normalized co-integrating coefficients (standard errors in parentheses)

CO_{2t}	GDP_{Ct}	GDP_{Ct}^2	GDP_{INDUt}	$MNFG_{Xt}$	$MNFG_{mt}$
1.000000	0.005047	-9.96E-06	-0.001151	0.006453	-0.000372
	(0.00048)	(1.1E-06)	(0.00408)	(0.00128)	(3.7E-05)

The co-integrating coefficients in Table 4.5 are long-run coefficients which captures the long-run relationship between CO_2 emission and the explanatory variables (GDP_{Ct}, GDP_{Ct}^2, GDP_{INDUt}, $MNFG_{Xt}$, $MNFG_{Mt}$). Mathematically this relationship can be expressed as;

$$CO_{2t} = 0.005047GDP_{Ct} - 9.96\text{E}^{-6}GDP_{Ct}^2 - 0.001151GDP_{INDUt} + 0.006453MNFG_{Xt} - 0.000372MNFG_{mt} \quad (4.1)$$

In order to decide on the statistical significance of each of the long-run relationship coefficients, we have to conduct t-test. The t-statistic (the calculated value) can be found by dividing the long-run coefficients with their respective standard errors from Table 4.5.

Table 4.6: t- statistic (the calculated value)

Variables	GDP_{Ct}	GDP_{Ct}^2	GDP_{INDUt}	$MNFG_{Xt}$	$MNFG_{Mt}$
coefficient	0.005047	-9.96E-06	-0.001151	0.006453	-0.000372
Standard error	(0.00048)	(1.1E-06)	(0.00408)	(0.00128)	(3.7E-05)
t-statistic	10.514583	-9.054545	-0.282107	5.041406	-10.054054

If we choose a significance level of 5% the critical values according to the t-distribution would be [-2.048409; 2.048409]. Except for the coefficient of the output share of the industry sector, the test values in Table 4.6 were located outside this interval. From equation (4.1) and Table 4.6, GDP per capita have a positive and statistically significant effect, the coefficient of squared GDP per capita is negative and statistically significant, the effect of the output share of the industry sector is negative but statistically insignificant, the ratio of manufacturing export to manufacturing GDP ($MNFG_{Xt}$) have a positive and statistically significant effect, and the coefficient of the ratio of manufacturing import to manufacturing GDP ($MNFG_{Mt}$) is negative and statistically significant.

According to model (3.2) a positive and statistically significant value for β_1, and a negative and statistically significant value of β_2, represents the existence of EKC for an environmental indicator. Accordingly, the results of the Johansen co-integration test indicate the existence of EKC for CO_2 emission in Ethiopia. However, it does not show which factor does exactly contribute for a reduced emission as per capita income increase. Alternatively, it does not show the contribution of each factor for a reduced emission in the process of economic development. Thus, an increase in income alone should not be considered as the solution of environmental problems.

The level of per capita income at which per capita CO_2 emission starts to diminish can be found as follows;

Take the first partial derivative of model (3.2) wrt GDP per capita and set it equal to zero

$$\frac{\partial CO_2}{\partial GDPc} = \beta_1 + 2\beta_2 GDPc = 0 \quad (4.2)$$

Or $GDP_c = -\frac{\beta_1}{2\beta_2}$

The estimated value of β_1 is 0.005047 and the value of β_2 is -9.96E-06. Thus;

$$GDP_c = -\frac{\beta_1}{2\beta_2} = \frac{0.005047}{-1.99E-05} = 253.36 \text{ Dollar}$$

GDP per capita is expected to capture the scale effect of economic activity on the quality of the environment. Its long-run coefficient is positive and statistically significant. That is, other things being equal the higher the output level -the higher the environmental degradation or pollution. A 1 dollar increase in per capita income causes a 0.005047 increase in CO_2 emission measured in metric tons of per capita. Squared GDP per capita will capture the technique effects (like environmental regulations, standards and/or environmental policies). The sign of the coefficient of squared GDP per capita is negative and statistically significant. One of the justifications for an inverted-u pattern (EKC) relationship between economic growth and environmental quality is the positive income elasticity of demand for environmental quality. That is, as people's income increase, their willingness-to-pay for a reduced emission and regulations will increase, then government start to enforce stringent environmental regulations which will result a reduced emission or environmental degradation. Thus, the negative sign of the squared GDP per capita coefficient might be taken as the effect of an increased income on environmental quality through its effect on environmental regulations, policies and/or standards.

The ratio of manufacturing export to manufacturing GDP and the ratio of manufacturing import to manufacturing GDP are introduced in order to capture the effect of international trade on environmental quality in the process of the economic development of the country. These two variables are expected to capture both the production and consumption patterns of an economy. A higher value of the ratio manufacturing export to manufacturing GDP implies that the country produces more manufacturing goods and sales in the international market. The manufacturing sector is assumed to be relatively pollution intensive. Thus, the production of more manufacturing goods implies higher emission. On the other hand, a higher value of the ratio of manufacturing import to manufacturing GDP shows that the country purchases more manufactured goods from the foreign market instead of producing them domestically.

The ratio of manufacturing export to manufacturing GDP has a positive and statistically significant coefficient. A 1% increase in the ratio of manufacturing export to manufacturing GDP will result in 0.006453 amount of CO_2 emission measured in metric tons of per capita. On the other hand, the sign of the coefficient of manufacturing import relative to manufacturing GDP is negative and statistically significant. A 1% increase in the ratio of manufacturing import to manufacturing GDP results in a 0.000372 decrease in CO_2 emission expressed in metric tons of per capita. The interpretation of these two coefficients is: in the sense that, if Ethiopia produces manufacturing goods instead of importing from the rest of the world, and if she imports manufacturing goods from the rest of the world instead of producing them domestically.

4.2.3. Error Correction Model (ECM) Estimation

The Johansen co-integration test indicates the existence of a long-run relationship among the variables in our model. However, this co-integration relationship does not capture the short-run dynamics in the system. Given that there exists co-integrating equations (long-run relationship), the error correction model (ECM) enables us to capture the short-run dynamics. The short-run estimation results from the ECM model where, the first difference of CO_2 emission is the dependent variable is given in Appendix B. However, most of the variables included in our ECM model are found to be statistically insignificant. So, it is better to search for a parsimonious specification by deleting the variables with insignificant coefficients to get the final short-run dynamic equation (ECM). But, we are not expected to delete all the variables with insignificant coefficients rather simply start from the highly insignificant variable and go through. By deleting the one period lag first difference of CO_2 emission, the two period lag first difference GDP per capita, the one period lag first difference of the output share of the industry sector, and the two period lag first difference of the ratio of manufacturing export to manufacturing GDP we arrived at our final parsimonious ECM model. The results from the parsimonious ECM model are given in Table 4.7.

Table 4.7: the Parsimonious ECM result

Variable	coefficient	Standard error	t-statistic	p-value
Constant	0.001210	0.001146	1.055957	0.3050
D(CO_2(-2))	0.564339	0.272951	2.067549	0.0534
D(GDP_C(-1))	0.000361	9.35E-05	3.864358	0.0011
D(GDP_{CSQ}(-1))	-6.60E-07	1.85E-07	-3.561507	0.0022
D(GDP_{CSQ}(-2))	-5.06E-08	4.17E-08	-1.213963	0.2405
D(INDGDP(-2))	0.002282	0.001002	2.277196	0.0352
D(MNFGm(-1))	1.43E-05	2.67E-05	0.536768	0.5980
D(MNFGx(-1))	0.000561	0.000414	1.352410	0.1930
D(MNFGx(-2))	0.000836	0.000406	2.057654	0.0544

R-squared	0.652419
F-statistic	3.071493
Prob (f-statistic)	0.016931
Durbin Watson stat	2.116079

Where 'D' stands for first difference of a variable, (-1) and (-2) represents the one period and the two period lag of a variable, respectively. In our parsimonious ECM model, the dependent variable is D(CO_2) or the first difference of CO_2 emission. The f-statistic and its corresponding probability from the estimation of the parsimonious error correction model (ECM) are found to be 3.071493 and 0.016931 respectively. The R-square value is ($R^2 = 0.652419$). From the f-test the p-value is less than 5% (it is 1.69%). It means that, the explanatory variables are jointly statistically significant to explain the dependent variable. And about 65.2% of the variation in the dependent variable is explained by the explanatory variables included in the model.

In the parsimonious ECM, the first two lags of both squared GDP per capita and the ratio of manufacturing export to manufacturing GDP are included. Thus, we have to check whether the first two lags of these variables are jointly statistically significant to explain CO_2 emission in the short run. The results from Wald-Test shows that, the first two lags of both squared GDP per capita and the ratio of manufacturing export to manufacturing GDP are jointly statistically significant to explain the short run fluctuation in CO_2 emission. The details of these test results are given in Appendix C.

From the Johansen test of co-integration we have found that there exist three co-integrating equations. It means that we have three error terms which adjusts the short-run disequilibrium. These error terms are the coefficients of the one period lag residual of the co-integrating equations. Table 4.8 provides the information about these coefficients, their standard errors, t-statistic, and the corresponding p-value.

Table 4.8: Adjustment parameters

Variable	Coefficient	Standard error	t-statistic	p-value
ECT1-1	-0.099311	0.040190	-2.471042	0.0425
ECT2-1	-0.000346	0.000102	-3.411124	0.0031
ECT3-1	0.000620	0.000401	1.545138	0.1388

Where ECT1-1 is the one period lag residual of the first co-integrating relationship, ECT2-1 is the one period lag residual of the second co-integrating equation, and ECT3-1 represents the one period lag residual of the third co-integrating equation.

The sign of the coefficient of the first error correcting term (ECT1-1) is negative and statistically significant which is desirable. The second error correcting term (ECT2-1) also has a negative and statistically significant coefficient which is also desirable. However the coefficient of the third error correcting term (ECT3-1) is positive and statistically insignificant which is not good from statistical point of view for an error correcting term. The coefficient of the first error correcting term can be interpreted as the first co-integrating equation adjusts short run-disequilibrium by 9.95% annually. And the coefficient of the second error correcting term says that, the second co-integrating equation adjusts short-run disequilibrium by 0.03% annually. However, the coefficient of the third error term does not have the desirable characteristics of an error correcting term. Since two out of three error terms has the desirable characteristics of an error correcting term, we can take our error correction model (ECM) as a good model to assess short run relationships.

Now we have to check how our model is good (efficient) from statistical point of view. The result of the Breusch-Godfrey Serial Correlation LM Test shows that the residual of the model is free from serial correlation. The Breusch-Pagan-Godfrey Heteroskedasticity Test result indicates that the variance of the residual of our model is homoscedastic. The Jarque-Bera normality test shows that the residual of the model is normally distributed. Overall, our model is good from statistical point of view. Appendix D provides the details of each of these tests. Next we have to check the stability of our model (or the stability of the parameters). The cumulative sum (CUSUM) test result shows that the model (or the parameters in our model) is stable. That is, there is no structural break in the economy in the rage of our sample period.

4.2.3. Impulse Response and Variance Decomposition

Impulse response traces out the responsiveness of the dependent variables (endogenous variable) in the VAR or VECM to shocks to each of the variables (Brooks, 2008). That is, impulse response shows, whether changes in the value of a given variable have a positive or negative effect on other variables in the system. A unit shock is applied to the error or innovation to see how it affects the whole VAR model. Provided that the system is stable, the shock should gradually die away (Brooks, 2008). An impulse response for CO_2 emission is given in Appendix E, figure E1.

Variance decomposition gives the proportion of the moments in the dependent variables that are due to their own shocks, versus shocks to other variables. A shock to the i^{th} variable directly affects the variable itself and also transmitted to other variables in the system through the dynamic structure of the VAR or VECM. Variance decomposition determines how much of the s-step-ahead forecast error variance of a given variable is explained by innovations to each explanatory variable (Brooks, 2008). The variance decomposition of CO_2 emission is indicated in Table 4.9;

Table 4.9: Variance Decomposition of CO2 emission

Period	S.E	CO2	GDPc	GDPcsq	INDGDP	MNFGm	MNFGx
1	0.005156	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.007636	95.13661	0.001565	0.030936	0.440231	4.388900	0.001756
4	0.023386	88.34235	0.805287	3.255973	3.722805	3.805079	0.068504
6	0.056054	86.28625	1.320013	3.001723	2.280244	6.999873	0.111902
8	0.104517	86.02492	1.321647	2.433496	2.046818	8.114802	0.058313
10	0.195739	86.06145	1.485644	2.994448	1.318815	8.060605	0.079041
12	0.384003	86.25956	1.406410	3.526947	1.186748	7.549962	0.070371
14	0.777693	86.52100	1.425504	3.424981	1.160773	7.392040	0.075704
15	1.106923	86.52794	1.399499	3.442544	1.224239	7.339128	0.066648

As can be observed from Table 4.8, in the long run, which is at period 15, about 86.5% of the forecast error variance of CO_2 emission is explained by CO_2 emission (own shock) while shock to the ratio of manufacturing import to manufacturing GDP (MNFGm) can cause 7.3% fluctuation in CO_2 emission. In the short run, at period 4, GDPcsq, INDGDP, and MNFGm accounts for an approximately equal variation of the forecast error variance of CO_2 emission.

Co-integration indicates that there exists causality between two time series variables but it fails to show the direction of the causal relationship. Hence, we have to conduct Granger causality test in order to know the direction of the causal relationship between variables in our system. The test result shows that, there is causality from GDP per capita and squared GDP per capita to CO_2 emission. Per capita GDP and squared GDP per capita are caused by all of the variables included in our system. Furthermore, the ratio of manufacturing import to manufacturing GDP, per capita GDP, and squared GDP per capita causes the ratio of manufacturing export to manufacturing GDP. There is no causality towards the output share of the industry sector and to the ratio of manufacturing import to manufacturing GDP from other variables in our system.

Chapter Five

Conclusions and Policy Implications

5.1. Conclusion

With an intention to examine the relationship between economic growth and environmental quality in Ethiopia, this study employs data spanning from 1981 to 2013. The descriptive part of the analysis provides the information about how our economy is carbon intensive. This analysis showed that even if GHG emission in general and the per capita CO2 emission in particular increase with an increase in income, it does not necessarily decrease when income falls. This gives some insight about the existence of factors other than the increase in income which may affect carbon emission. Economic theory suggests that structural change (that is if the economy shifts from less polluting sectors to more polluting sectors) and technical effects (or with in the sector the technologies applied in the production process) may contribute for GHG emission positively.

In order to meet its specific objective (or to investigate EKC for CO_2 emission), the study applies Johansen co-integration and error correction model (ECM) techniques. Results from the Johansen test of co-integration indicates that per capita income has a positive and statistically significant effect on CO_2 emission and the effect of squared GDP per capita is negative and also statistically significant. Hence, EKC holds for CO_2 emission in Ethiopia.

In the modeling of the environmental Kuznets curve (EKC) we are more concerned to incorporate variables representing structural change in the output composition of the economy, international trade, and democracy. The output share of the industry sector (GDP_{INDUt}) is assumed to capture the effect of structural change of the economy on CO_2 emission. The long-run parameter estimation result from the Johansen co-integration test gives a negative but statistically insignificant effect of this variable on CO_2 emission. This study incorporates two variables to capture the effect of international trade on CO_2 emission; the ratio of manufacturing export to manufacturing GDP ($MNFG_{Xt}$) and the ratio of manufacturing import to manufacturing GDP ($MNFG_{Mt}$). These variables are expected to capture the change in output and consumption composition in an economy as a result of international trade as a country develops. The estimated parameter results show that, the higher the value of the manufacturing export relative to manufacturing GDP-the higher the per capita CO_2 emission, and the higher the ratio of manufacturing import to manufacturing GDP-the lower the level of per capita CO_2 emission. Hence, future research on the relationship between economic growth and environmental policy should focus on incorporating variables representing environmental policies, structural change, international trade or democracy.

5.2. Policy Implications

From the descriptive part of our analysis we had conclude that, there are other factors other than the increase in income which contributes for CO_2 emission positively. This implies that factors representing environmental policies, structural change of an economy, institutional qualities to enforce environmental regulations and/or standards, and international trade have to be taken into account in the analysis of the relationship between economic growth and environmental quality. For instance, Ethiopia may have well-articulated (or clearly defined) environmental policies but, if institutions are weak to enforce the environmental regulations and/or standards, then the environmental policies are not different from any ordinary written document. Thus, environmental policies will not bring solutions to environmental degradation or pollution by themselves; they need strong institutions to be enforced. Likewise, the production pattern of the economy may move from less polluting sector to more polluting and highly energy intensive sector. This structural change may cause high environmental degradation or pollution no matter the level of per capita income. Therefore, factors what we have mentioned here must be taken in to account in the analysis of the growth-income relationship.

Our estimation result supports this justification. When we compare the estimated parameters of GDP per capita and the ratio of manufacturing export to manufacturing GDP, the ratio of manufacturing export to manufacturing GDP have a greater positive effect on CO_2 emission in magnitude. Furthermore, the effect of the ratio of manufacturing import to manufacturing GDP is negative and significant. These international trade variables have implications about environmental regulations and the quality of institutions in a country. Countries with strict environmental policies, regulations and/or standards are likely to import manufacturing goods from other countries instead of producing domestically. In contrast countries with relaxed environmental policies and standards are likely to produce manufacturing goods and sale to the international community.

We have found an EKC pattern relationship between CO_2 emission and per capita income. However, it does not mean that an increase in income by itself will solve environmental problems associated with growth. Rather it needs environmental policies, regulations and/or standards in combination with strong institutions to enact the environmental policies.

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Appendices

Appendix A: Johansen Co-integration Test

Date: 05/31/17 Time: 19:51

Sample (adjusted): 1984 2013

Included observations: 30 after adjustments

Trend assumption: Linear deterministic trend

Series: CO_2GDPC GDPCSQ INDGDP MNFGM MNFGX

Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.938111	190.7512	95.75366	0.0000
At most 1 *	0.816903	107.2790	69.81889	0.0000
At most 2 *	0.633437	56.34685	47.85613	0.0065
At most 3	0.488781	26.23927	29.79707	0.1217
At most 4	0.184123	6.110557	15.49471	0.6825
At most 5	0.000194	0.005816	3.841466	0.9385

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.938111	83.47223	40.07757	0.0000

At most 1 *	0.816903	50.93217	33.87687	0.0002
At most 2 *	0.633437	30.10758	27.58434	0.0232
At most 3	0.488781	20.12871	21.13162	0.0686
At most 4	0.184123	6.104741	14.26460	0.5998
At most 5	0.000194	0.005816	3.841466	0.9385

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Long run coefficients

1 Cointegrating Equation(s): Log likelihood -528.1702

Normalized cointegrating coefficients (standard error in parentheses)

CO2	GDPC	GDPCSQ	INDGDP	MNFGM	MNFGX
1.000000	0.005047	-9.96E-06	-0.001151	-0.000372	0.006453
	(0.00048)	(1.1E-06)	(0.00408)	(3.7E-05)	(0.00128)

Appendix B: Short run estimation result (ECM)

Dependent Variable: D(CO2)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Date: 05/31/17 Time: 19:59

Sample (adjusted): 1984 2013

Included observations: 30 after adjustments

D(CO2) = C(1)*(CO2(-1) - 0.00510241896205*INDGDP(-1) +
4.6722226435E-05*MNFGM(-1) + 0.000442224632462*MNFGX(-1) -
0.0221618494756) + C(2)*(GDPC(-1) + 134.810981898*INDGDP(-1)
- 1.82551268555*MNFGM(-1) - 11.5861369767*MNFGX(-1) -
1090.28116666) + C(3)*(GDPCSQ(-1) + 67902.2817879*INDGDP(-1)
- 882.808626428*MNFGM(-1) - 6473.16363249*MNFGX(-1) -
496205.566407) + C(4)*D(CO2(-1)) + C(5)*D(CO2(-2)) + C(6)
*D(GDPC(-1)) + C(7)*D(GDPC(-2)) + C(8)*D(GDPCSQ(-1)) + C(9)
*D(GDPCSQ(-2)) + C(10)*D(INDGDP(-1)) + C(11)*D(INDGDP(-2)) +
C(12)*D(MNFGM(-1)) + C(13)*D(MNFGM(-2)) + C(14)*D(MNFGX(-1)) +
C(15)*D(MNFGX(-2)) + C(16)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.169807	0.047124	-3.603406	0.0048
C(2)	-0.000513	0.000201	-2.559457	0.0284
C(3)	7.85E-07	4.21E-07	1.863874	0.0834
C(4)	0.130193	0.474764	0.274227	0.7879
C(5)	0.629571	0.416425	1.511845	0.1528
C(6)	0.000408	0.000172	2.377973	0.0322
C(7)	5.71E-05	0.000205	0.277945	0.7851
C(8)	-7.56E-07	3.46E-07	-2.187405	0.0462
C(9)	-1.76E-07	4.38E-07	-0.402184	0.6936
C(10)	-6.84E-05	0.001170	-0.058426	0.9542
C(11)	0.002255	0.001160	1.944081	0.0723
C(12)	1.50E-05	3.05E-05	0.490841	0.6311

C(13)	-8.48E-06	3.43E-05	-0.247351	0.8082
C(14)	0.000488	0.000474	1.029612	0.3207
C(15)	0.000847	0.000733	1.155272	0.2673
C(16)	0.001256	0.001978	0.635009	0.5357

R-squared	0.765209	Mean dependent var	0.002142
Adjusted R-squared	0.310146	S.D. dependent var	0.006208
S.E. of regression	0.005156	Akaike info criterion	-7.392617
Sum squared resid	0.000372	Schwarz criterion	-6.645312
Log likelihood	126.8893	Hannan-Quinn criter.	-7.153548
F-statistic	3.566060	Durbin-Watson stat	2.238770
Prob(F-statistic)	0.022374		

Most of the variables in our ECM are statistically insignificant. Hence, we have developed the following parsimonious version of our ECM by deleting some of the insignificant variables.

The parsimonious ECM estimation result

Dependent Variable: D(CO2)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 06/20/17 Time: 12:09
Sample (adjusted): 1984 2013
Included observations: 30 after adjustments
D(CO2) = C(1)*(CO2(-1) - 0.00510241896205*INDGDP(-1) + 4.6722226435E-05*MNFGM(-1) + 0.000442224632462*MNFGX(-1) - 0.0221618494756) + C(2)*(GDPC(-1) + 134.810981898*INDGDP(-1) - 1.82551268555*MNFGM(-1) - 11.5861369767*MNFGX(-1) - 1090.28116666) + C(3)*(GDPCSQ(-1) + 67902.2817879*INDGDP(-1) - 882.808626428*MNFGM(-1) - 6473.16363249*MNFGX(-1) - 496205.566407) + C(5)*D(CO2(-2)) + C(6)*D(GDPC(-1)) + C(8)*D(GDPCSQ(-1)) + C(9)*D(GDPCSQ(-2)) + C(11)*D(INDGDP(-2)) + C(12)*D(MNFGM(-1)) +C(14)*D(MNFGX(-1)) + C(15)*D(MNFGX(-2)) + C(16)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.099311	0.040190	-2.471042	0.0425
C(2)	-0.000346	0.000102	-3.411124	0.0031
C(3)	0.000620	0.000401	1.545138	0.1388
C(5)	0.564339	0.272951	2.067549	0.0534
C(6)	0.000361	9.35E-05	3.864358	0.0011
C(8)	-6.60E-07	1.85E-07	-3.561507	0.0022
C(9)	-5.06E-08	4.17E-08	-1.213963	0.2405
C(11)	0.002282	0.001002	2.277196	0.0352

C(12)	1.43E-05	2.67E-05	0.536768	0.5980
C(14)	0.000561	0.000414	1.352410	0.1930
C(15)	0.000836	0.000406	2.057654	0.0544
C(16)	0.001210	0.001146	1.055957	0.3050

R-squared	0.652419	Mean dependent var	0.002142
Adjusted R-squared	0.440008	S.D. dependent var	0.006208
S.E. of regression	0.004646	Akaike info criterion	-7.616526
Sum squared resid	0.000389	Schwarz criterion	-7.056047
Log likelihood	126.2479	Hannan-Quinn criter.	-7.437224
F-statistic	3.071493	Durbin-Watson stat	2.116079
Prob(F-statistic)	0.016931		

Appendix C: Coefficient Diagnostic Test from the parsimonious ECM

Wald Test:

Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	6.981783	(2, 18)	0.0121
Chi-square	13.96357	2	0.0021

Null Hypothesis: C(8)=C(9)=0

Where C(8) and C(9) are the coefficient for D(GDPcsq(-1)) and D(GDPcsq(-2)) respectively. The null hypothesis is C(8) and C(9) are jointly zero to explain CO_2 emission. When we look at the chi-square statistic (13.96357) and its corresponding probability (0.0021), the p-values is less than 5% (or it is 0.21%). So we can reject the null hypothesis. It means that the first two lags of squared GDP per capita are jointly statistically significant to explain CO_2 emission. That is, there is a short-run relationship between CO_2 emission and squared GDP per capita.

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	2.526941	(2, 18)	0.1078
Chi-square	5.053883	2	0.0799

Null Hypothesis: C(14)=C(15)=0

Where C(14) and C(9) are the coefficients for D(MNFGx(-1) and D(MNFGx(-2)) respectively. The chi-square statistic (5.053883) and its corresponding probability is 7.99% which is less than 10%. We can reject the null hypothesis: C(8)=C(9)=0, meaning there is a short run relationship between CO_2 emission and the ratio of manufacturing export to manufacturing GDP.

Appendix D: Model Efficiency Tests

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.586576	Prob. F(2,12)	0.5714
Obs*R-squared	2.671689	Prob. Chi-Square(2)	0.2629

Test Equation:

Dependent Variable: RESID

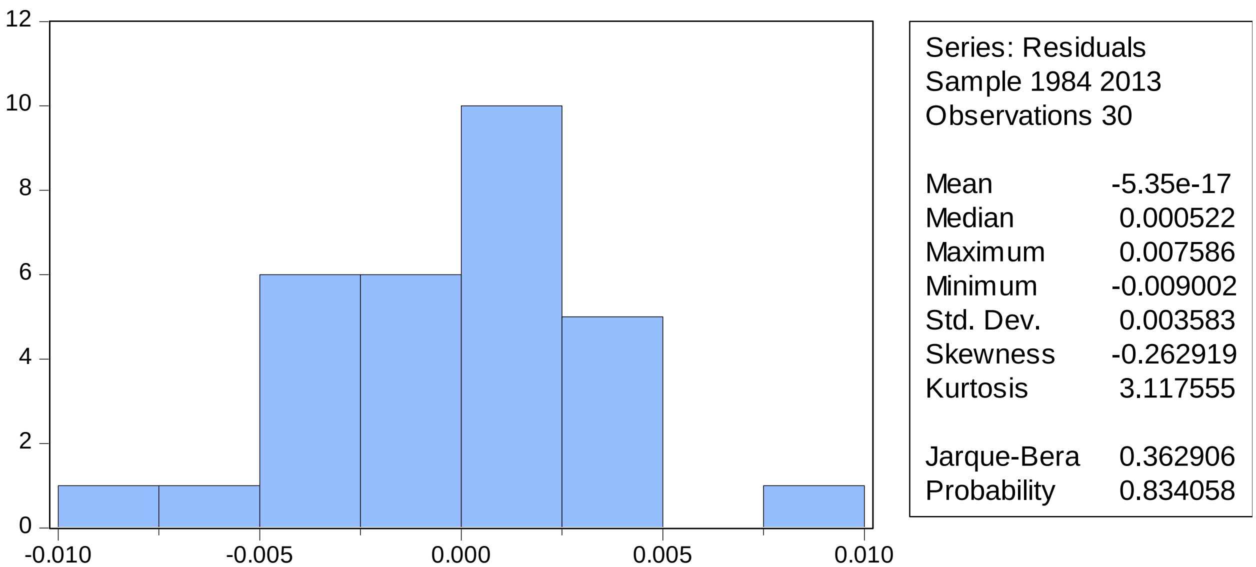
Where 'RESID' is residual, here the null hypothesis is that the residual of the model is free from serial correlation. The observed r-square statistic is 2.671689 and the corresponding probability is 26.29% which is more than 5%. Since the p-value is more than 5%, we cannot reject the null hypothesis that the residual of the model are not serial correlated. This is desirable for a good model.

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.363812	Prob. F(18,11)	0.3045
Obs*R-squared	20.71694	Prob. Chi-Square(18)	0.2939
Scaled explained SS	4.776875	Prob. Chi-Square(18)	0.9992

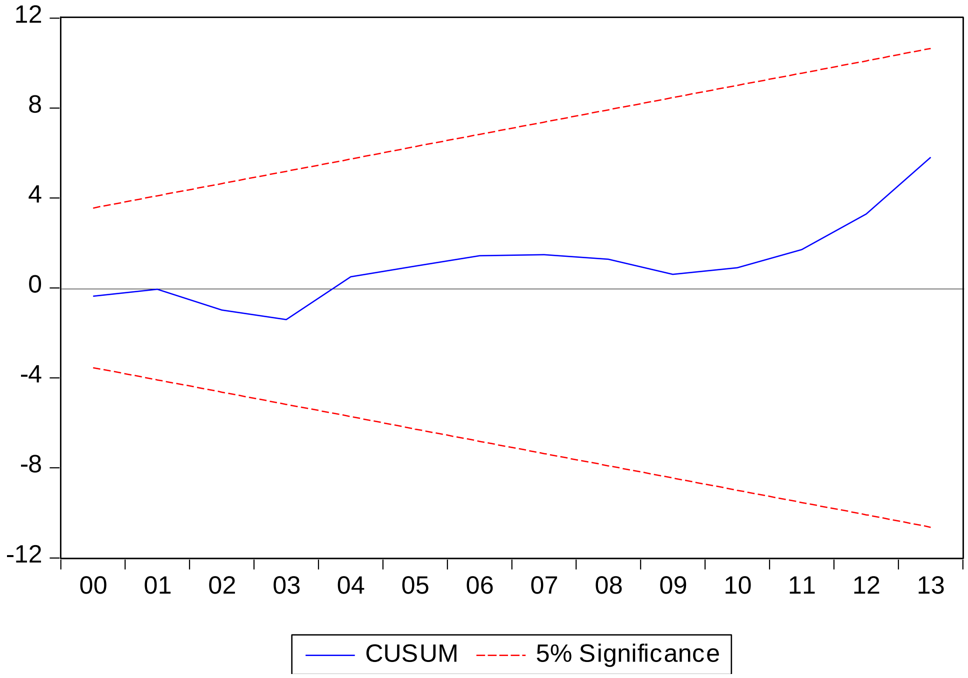
In this heteroskedasticity test the null hypothesis is the variance of the residual is not heteroskedastic (or the variance of the residual is homoscedastic). The statistic of the observed r-square and its corresponding chi-square probability are 20.71694 and 0.2939 respectively. The p-value is 29.39% and the guideline is if the p-value is more than 5% we cannot reject null hypothesis rather we accept it. It means that the variance of the residual in our model is homoscedastic.

Figure D1: Histogram-residual normality test



As can be observed from the above figure the Jarque-Bera test statistic is 0.362906 and its corresponding probability is 0.834058. Here the null hypothesis is the residual of the model is normally distributed. Since the p- value is more than 5% (it is 83.4%), we fail to reject the null hypothesis. Thus, the residual of our model is normally distributed which is a desirable characteristic of a good model.

Figure D2: CUSUM test for model stability



The CUSUM test line lies between the two dashed lines. It means that we fail to reject the null hypothesis (here the null hypothesis is: there is no structural break) at 5% level of significance. Thus, our parameters are stable or there is no structural break with in the range of our sample period.

Appendix E: Impulse Response and Variance Decomposition of CO2 emission

Figure E1: Impulse response of CO_2 emission

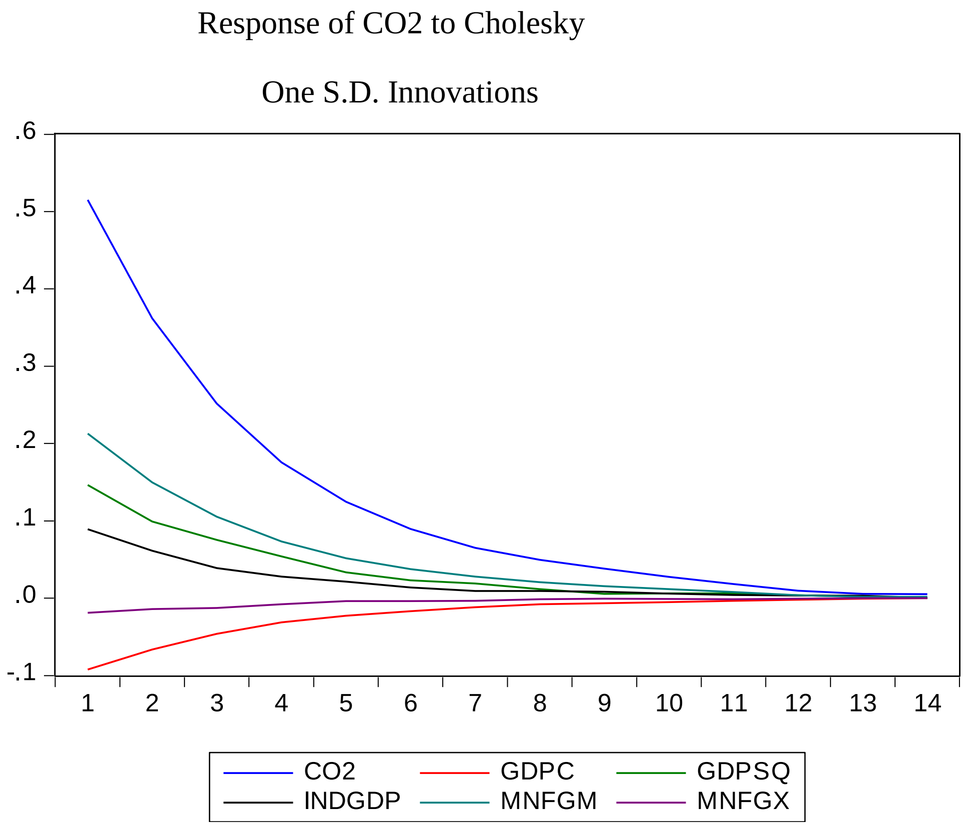


Figure E1 illustrates the response of carbon dioxide (CO_2) to shocks in income per capita and squared per capita income , the output share of the industry sector, the ratio of manufacturing export to manufacturing GDP, the ratio of manufacturing import to manufacturing GDP, and carbon dioxide (CO_2). As can be shown from the figure, the response of CO_2 to shocks in per capita GDP and the ratio of manufacturing export to manufacturing GDP are negative, and it decreases over time in magnitude. The response to the remaining variables is positive and decreases over time.

Variance Decomposition of CO_2 Emission

Variance Decomposition of CO2: Period	S.E.	CO2	GDPC	GDPCSQ	INDGDP	MNFGM	MNFGX
1	0.005156	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.007636	95.13661	0.001565	0.030936	0.440231	4.388900	0.001756
3	0.012889	87.99685	0.238796	2.536127	5.520044	3.705832	0.002347
4	0.023386	88.34235	0.805287	3.255973	3.722805	3.805079	0.068504
5	0.037917	86.46431	1.125102	3.863947	2.625785	5.747833	0.173020
6	0.056054	86.28625	1.320013	3.001723	2.280244	6.999873	0.111902
7	0.077275	86.38131	1.370628	2.093671	2.305395	7.778424	0.070573
8	0.104517	86.02492	1.321647	2.433496	2.046818	8.114802	0.058313
9	0.142546	85.71352	1.388624	3.057936	1.530368	8.225255	0.084292
10	0.195739	86.06145	1.485644	2.994448	1.318815	8.060605	0.079041
11	0.271913	86.32332	1.469588	3.060859	1.301846	7.785110	0.059280
12	0.384003	86.25956	1.406410	3.526947	1.186748	7.549962	0.070371
13	0.546801	86.32470	1.408727	3.639298	1.095449	7.443548	0.088281
14	0.777693	86.52100	1.425504	3.424981	1.160773	7.392040	0.075704
15	1.106923	86.52794	1.399499	3.442544	1.224239	7.339128	0.066648

Granger-Causality test

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 06/23/17 Time: 08:33
Sample: 1981 2013
Included observations: 30

Dependent variable: D(CO2)

Excluded	Chi-sq	df	Prob.
D(GDPC)	12.29197	2	0.0021
D(GDPCSQ)	9.464183	2	0.0088
D(INDGDP)	4.041833	2	0.1325
D(MNFGM)	0.296971	2	0.8620
D(MNFGX)	1.957639	2	0.3758
All	18.92020	10	0.0413

Dependent variable: D(GDPC)

Excluded	Chi-sq	df	Prob.
D(CO2)	56.01231	2	0.0000
D(GDPCSQ)	115.5754	2	0.0000
D(INDGDP)	45.37833	2	0.0000
D(MNFGM)	27.06294	2	0.0000
D(MNFGX)	50.02504	2	0.0000

All	210.3653	10	0.0000

Dependent variable: D(GDPCSQ)

Excluded	Chi-sq	df	Prob.
D(CO2)	28.89075	2	0.0000
D(GDPC)	67.55653	2	0.0000
D(INDGDP)	39.43538	2	0.0000
D(MNFGM)	17.79924	2	0.0001
D(MNFGX)	32.64957	2	0.0000
All	163.3861	10	0.0000

Dependent variable: D(INDGDP)

Excluded	Chi-sq	df	Prob.
D(CO2)	3.113400	2	0.2108
D(GDPC)	0.748455	2	0.6878
D(GDPCSQ)	1.013465	2	0.6025
D(MNFGM)	0.452379	2	0.7976
D(MNFGX)	2.224239	2	0.3289
All	13.08644	10	0.2189

Dependent variable: D(MNFGM)

Excluded	Chi-sq	df	Prob.
D(CO2)	0.969322	2	0.6159
D(GDPC)	1.445138	2	0.4855
D(GDPCSQ)	1.262527	2	0.5319
D(INDGDP)	3.807224	2	0.1490
D(MNFGX)	3.459660	2	0.1773
All	13.70777	10	0.1867

Dependent variable: D(MNFGX)

Excluded	Chi-sq	df	Prob.
D(CO2)	0.638171	2	0.7268
D(GDPC)	17.68852	2	0.0001
D(GDPCSQ)	20.83772	2	0.0000
D(INDGDP)	1.797511	2	0.4071
D(MNFGM)	7.755888	2	0.0207
All	35.62328	10	0.0001

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree award in any other university. All sources of materials used for the thesis have been duly acknowledged and examiners comments have been incorporated.

Declared by: Gelagay Yeneneh

Signature: _____________

Date: ________________

Confirmed by Advisor: Wassie Berhanu (PhD)

Signature: _______________

Date: _________________