



OULUN YLIOPISTO
UNIVERSITY of OULU

OULU BUSINESS SCHOOL

Adeleye Adetunji

**EXAMINING THE IMPACT OF ECONOMIC GROWTH ON ENVIRONMENTAL
QUALITY**

Master's Thesis

Economics

December 2017



ABSTRACT OF THE MASTER'S THESIS

Unit Department of Economics			
Author Adeleye Adetunji		Supervisor Professor Mikko Puhakka	
Title Examining the impact of economic growth of environmental quality			
Subject Economics	Type of the thesis Master's Thesis	Time of publication December 2017	Number of pages 55
<p>Abstract</p> <p>The relationship between the environment and the economy is broad, and it invites careful analysis and attention. Which explains why this thesis seeks to examine the impact of economic growth on environmental quality. Meanwhile, the concern that gave rise to this topic is the strategy adopted by developed countries in their early growth stage which was to “grow rich first and clean up later”.</p> <p>The theoretical framework on which this thesis stands is the Environmental Kuznets Curve (EKC) which suggests that environmental degradation first increase, then level off, and decrease as economic growth takes place. In other words, there is an inverted-U shaped relationship between economic growth and the environment. Past studies have shown that not all environmental problems follow this inverted-U curve model and some others have gone further to suggest alternative models to explain the nexus between the environment and the economy such as overlapping generation's model and Commoner-Ehrlich equation model, which were reviewed in this thesis.</p> <p>Our goal was to assess whether economic growth positively contributed to environmental quality and assess the validity of the inverted-U curve model. The empirical investigation was carried out using panel data from 70 countries spread between high, middle and low-income countries as classified by the World Bank and period coverage between 1998 to 2013. This thesis uses CO₂ emissions per capita as a proxy for environmental quality. Furthermore, two-ways fixed effect estimator was used in the econometric analysis to account for country and time specific effects in the model, and joint F statistic test was employed to test the statistical significance of the model used and justify the inclusion of the quadratic and cubic transformations of GDP per capita.</p> <p>This thesis discovers a slight improvement in environmental quality after episodes of environmental degradation, which somewhat agrees with the EKC hypothesis. However, disaggregation of our data indicates increase in CO₂ emissions for high-income countries after episodes of reduction, a stark contrast to the position of the EKC. The nonlinearity of the relationship between GDP per capita and CO₂ emission reflects how complicated and unstable environmental problems can be. This result can significantly help policymakers to be proactive in managing the environment.</p>			
Keywords Economic growth, Environmental Kuznets Curve, CO ₂ emissions, Trade Openness, Environment.			

Contents

1	INTRODUCTION.....	5
2	CONCEPTUAL AND THEORETICAL FRAMEWORK	7
	2.1 Economic growth and Industrial Revolutions.....	7
	2.2 Statement of the problem; Grow now, clean up later.....	8
	2.3 Research Objectives	10
	2.4 Literature Review	11
	2.3.1 The Environmental Kuznets Curve.....	11
	2.3.2 The Commoner-Ehrlich Equation Model: A consumption-based approach	18
	2.3.2 Overlapping Generations Model of Growth and the Environment...	21
3	RESEARCH METHODS.....	24
	3.1 Drivers of environmental impact.....	24
	3.2 Data Selection	24
	3.2.1 Dependent Variable	24
	3.2.2 Independent Variables	25
	3.3 Regression model.....	27
4	RESULTS AND ANALYSIS	28
	4.1 Estimation Method.....	28
	4.2 Empirical Analysis	30
	4.2.1 Statistical test for significance of regression model and EKC hypothesis.....	34
	4.2.2 Discussion of Regression Results	35
	4.3 Summary of findings.....	38
5	POLICY RECOMMENDATIONS AND CONCLUSIONS.....	41
	5.1 Policy Recommendations.....	41
	5.2. Conclusion	42
	REFERENCES.....	44

APPENDIX	51
-----------------------	-----------

FIGURES:

Figure 1. CO₂ emissions from fossil fuel use and cement production (1990 -2016) (Source: Netherlands Environmental Assessment Agency).....	10
Figure 2. Environmental Kuznets Curve	12
Figure 3. Scatter plot of Carbon dioxide emission per capita and GDP per capita (1998-2013)	53
Figure 4. Scatter plot of CO₂ emissions and Population density (1998 – 2013)	53
Figure 5. Scatter plot of CO₂ emission per capita and energy intensity (1998 – 2013)	54
Figure 6. Scatter plot of CO₂ emission per capita and real growth rate (1998 – 2013).....	54
Figure 7. Scatter plot of CO₂ emission per capita and share of urban population (1998 – 2013)	55
Figure 8. Scatter plot of CO₂ emission per capita and trade openness (1998 – 2013)	55

Tables:

Table 1.Results of past studies explaining the environmental quality-income relationships	14
Table 2. Theoretical concepts and their indicators	26
Table 3. Descriptive statistics – sample: all countries	30
Table 4. Correlation matrix of Independent variables (1998-2013).....	31
Table 5. Different estimators of CO₂ Emissions	32
Table 6. Results of F statistic tests	35
Table 7. Different estimators of CO₂ emissions for high, middle and low income countries	36
Table 8. Countries in the panel data set	51

1 INTRODUCTION

Man was made for the environment and the environment was made for man. Science has consistently highlighted this symbiotic relationship; however, man's dominance goes without saying in the way he has repeatedly used the environment as a resource to meet the necessities of life.

Many natural amenities and gifts of nature such as fresh air, trees, clean water, open spaces, wildlife and so on have been sacrificed as a result of man's insatiable desire to live a good life and find satisfaction. It is clearly evident from time immemorial there has been a struggle for dominance between man and nature. While it is apparent man has claimed the upper hand by effectively using these natural resource endowments as inputs in production process to produce goods and services.

However, for all these value creation from economic activities, bitter pills are left behind in the environment for man to taste and grapple with in the form of air pollution, eutrophication of water bodies, destruction of wilderness, noise pollution, ozone depletion etc. exposing man to several health hazards. In a manner of speaking, the environment has its subtle way of fighting back.

There are fundamental issues at play here; which are free will, choice and consequences. This provides the conceptual framework upon which we understand the complex relationship between economics and environment. Man has free will, exercises it over the environment to meet survival needs, and chooses what is best to meet this objective, however, forgetting that there are boundaries to his free will. In other words, once a choice is made you cannot determine the consequence that follows and furthermore, man is also an innate part of the environment he exploits.

Now, because of this tight connectedness or interdependence, every act of choice or every manipulation of the environment sets off chains of repercussions, often uncontrollable, through the entire environment system (Barkley and Seckler 1972). For instance, consider the intended consequence of oil drilling and exploration which is to meet our daily energy consumption needs; however, its unintended effects, which

are undesirable, consist of disasters such as oil spills, air pollution, and corrupt practices.

Therefore, in a way, finding a solution creates another problem, and this gives definition to environmental economics; which is the study of unintended consequences of choices (Barkley and Seckler 1972).

This thesis is structured as follows: the next chapter contains the conceptual and theoretical framework upon which we build our understanding of the relationship between economic growth and the environment. It further presents various theoretical arguments relevant to the thesis. Chapter 3 describes the research methods and data employed for the empirical research. Chapter 4 presents the regression estimations, empirical analysis, summarises the finding. Finally, chapter 5 discusses the policy recommendation and conclusion.

2 CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1 Economic growth and Industrial Revolutions

Industrialisation, the process of economic transformation through economic activities such as agriculture and manufacturing dates back to the mid-eighteen century, precisely to the year 1750 (Tilly 2010) and the revolutions spread across three time periods.

Great Britain spearheaded the first period from the year 1750 to 1870 which is known as the early industrialisation. This period was largely driven by an agrarian system of occupation, it concentrated on land ownership and food crop production for subsistence purposes. Coal and steam engines powered the locomotives for transportation and other mechanical activities.

The second period (1870-1914) otherwise known as rapid industrialisation period. In this period, the chain of industrial activity had spread to other western European countries. Systematic application of science to technology saw the rapid growth and transition from labour intensive to capital-intensive industries. Discovery of fossil fuel to oil the industrial process and excess of capital resulted in the improvement of agricultural practices, rise of steel and manufacturing industries. Furthermore, factory work became complex because of mass production lines to satisfy demands and rising consumption patterns. The principle of comparative advantage governed the operations of international trade and witnessed increased trade volumes across continents.

The third period (1918 to late twentieth century) was marred by two world wars and the great depression of 1929 to 1933. However, it did not deter massive investments in social overhead capitals like dams, railways, bridges, etc. to boost directly productive activities and stimulate economic growth. Through the use of earth materials, inventions such as electrical appliances and electronic equipment, automobiles, airplanes, shipping vessels and computer technology were produced and during this industrial revolution, western economies were growing at an increasing rate.

Now a fourth industrial revolution is on the horizon. A recombination of previous revolutions defined by Artificial Intelligence (AI), robotics, nanotechnology, Internet of Things (IoT), energy storage, autonomous vehicles and 3D printing (Schwab 2017). Although, it promises to place less burden on the environment, unlike previous revolutions, in terms degradation and pollution, and transform business models for better service delivery. However, it presents potential risk of job losses and inequality.

2.2 Statement of the problem; Grow now, clean up later

This phrase seems to reflect the attitude of developed countries during the early stage of their economic growth. Rapid growth came at a cost. John Stuart Mill was the first economist in 1904 to succinctly capture this reality by recognizing that growth of production might be at the expense of environmental enjoyments by saying:

It is not good for man to be kept perforce at all times in the presence of his species. A world from which solitude is extirpated is a very poor ideal. Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature. If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not a better or happier population. I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it. (Mill 1904: 454)

In aggressive attempts to grow and provide for an increasing population, developed countries unconsciously followed this development pattern; grow now, consequences notwithstanding, and clean up the mess that follows later. Retrospectively, this growth model did not appear to be a sound idea, as the consequence was as bad as the phrase, grow now clean up later suggests. Development experience of developed countries provides evidence to this argument. The economy of Japan, immediately after World War II, improved by leaps and bounds. Recording 12% annual growth rate in the latter half of the 1960s (Kato 1998). However, this economic growth gave rise to episodes of air, water and soil pollution across the country, particularly in large cities such as Yokohama, Tokyo, and Osaka. The industrial poisoning of Minamata Bay was a sad event worth noting. The largest employer in the Port town, Chisso Corp., discharged

poisonous mercury into the bay area consequently claiming thousands of lives (Time 1975).

The United States of America (USA) also experienced its fair share of environmental disaster arising from increased economic activity. One of such occurred in 1969 when the Cuyoga River in Ohio, thick with pollutants and bereft of fish, caught fire (The Economist, 2013). Actually, that was the thirteenth time of occurrence and it was discovered that all of the industries in the area indiscriminately dump their waste in the river untreated.

The damaging effect of these environmental destructive activities, according to Brown *et al.* (1993), are now showing up in reduced productivity of croplands, forests, grasslands and fisheries; in the mounting cleaning up costs of toxic waste sites; in rising health care costs for cancer, birth defects, allergies, emphysema, asthma and other respiratory diseases; and in the spread of hunger. Also important to note is the significant contribution of economic activities to the atmosphere's greenhouse gas emissions such as Carbon dioxide (CO₂), chlorofluorocarbons, methane, nitrous oxide and other gases. This situation has led scientists to speculate further increase in the earth's average surface temperature and ultimately, climate change.

According to Ekins (2000), Carbon dioxide levels in the atmosphere have risen about 25 per cent since pre-industrial times due to human activities. Figure 1 below, shows the growth of emissions of carbon dioxide from fossil fuel burning and cement production since 1990. It shows that the European Union (EU) member states, Japan, Russia, and the USA, the largest emitter of the developed countries, are recording some reduction in emission levels. In contrast, emission levels in India, China and the rest of the world show rising trends even though, recently, China seems to be taking significant steps to reverse this trend. A possible explanation for these rising emission trend levels is the need for rapid economic growth and also catch up with the leading economies.

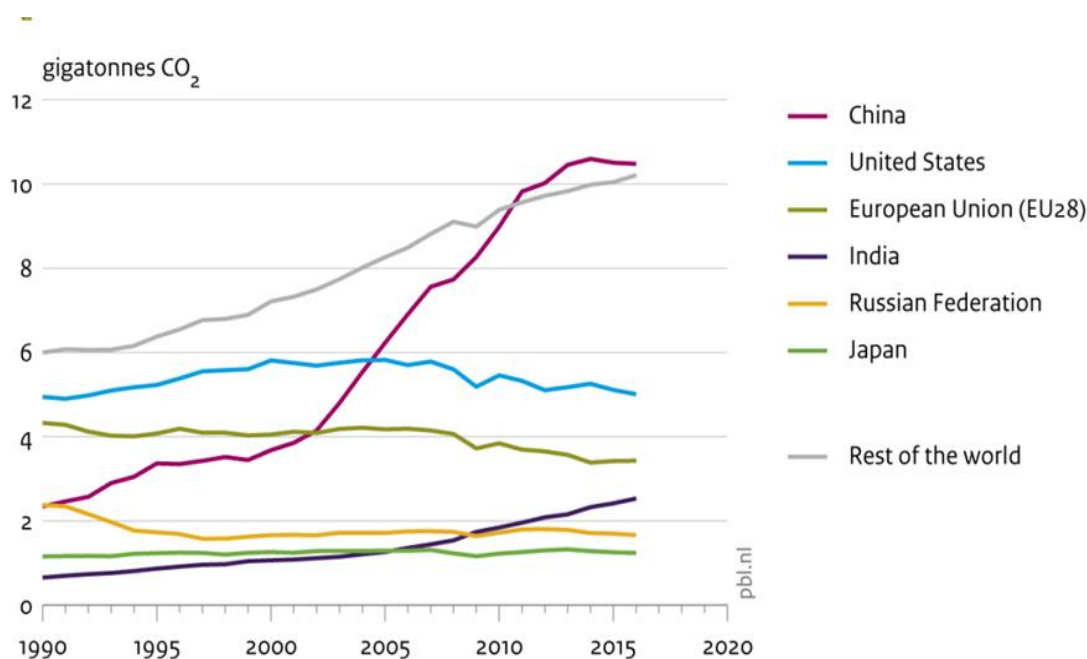


Figure 1. CO₂ emissions from fossil fuel use and cement production (1990 -2016)
 (Source: Netherlands Environmental Assessment Agency)

2.3 Research Objectives

The focus of this thesis is to investigate the impact economic growth has on environmental quality. This will be done using recent data sets to reflect the reality of modern trends. Research is considered a useful tool to investigate a case to arrive at an objective conclusion systematically and in previous years substantial amount of research has been devoted to explaining the relationship between economic growth and environmental quality.

Hence, the research goal of this master's thesis will be to assess whether economic growth has positive impact on environmental quality and assess the validity of the inverted U curve model relationship between per capita GDP and environmental quality.

2.4 Literature Review

The relationship between economic growth and environmental quality has been a source of growing conflict among academic scholars over the years, where finding common ground seems to be almost impossible. The traditional economic theory posits a trade-off between economic growth and environmental quality. This subject has split policymakers into two lines of reasoning. Developed countries, now coming to terms with the environmentally profligate policies of the past, are currently concerned about the long run effects of global environmental degradation, while developing countries, on the other hand, are concerned more with survival than greenery, seek faster growth (John and Pecchenino 1994).

2.3.1 The Environmental Kuznets Curve

Well documented academic and empirical works of literature available on the Environmental Kuznets Curve (EKC) since the early 1990s suggests that the relationship between economic growth and environment could be positive noting that growth is a prerequisite for environmental improvement. This invites careful analysis. Many of these existing literature will be expounded on in this literature reviews.

The EKC was modelled after the work of Simon Kuznets, a Russo-American economist, in *The American Economic Review Journal* of March 1955. Therein, Kuznets (1955) predicted that the changing relationship between per capita income and income inequality follows an inverted-U shaped curve. Meaning that, as per capita income increases, income inequality also increases at first and then starts declining after a turning point. In other words, the distribution of income becomes unequal in early stages of income growth and then the distribution moves towards decreasing economic inequality as economic growth continues (Kuznets 1955). This explanation is popularly termed as the Kuznets Curve (shown in Figure 2).

Going forward, Kuznets Curve has been adopted for other academic and scholarly purposes. It has become a vehicle for describing the relationship between measured levels of environmental quality and per capita income. Now known as the Environmental Kuznets Curve (EKC), first labeled so by Panayotou (1993).

The logic underlying the EKC is that in the course of a country's economic development, increasing national income increases the scale of economic activity, which all else being equal, leads to rising pollution levels (scale effect). However, after a certain threshold of national income has been reached, pollution is supposed to decline due to two effects: first, the composition of the economy is likely to change from manufacturing to service (composition effect). Second, with rising national income, technological progress tends to lead to less environmental pollution (technology effect). Furthermore, there is a political dimension to the EKC, which implies that at early stages of economic development, environmental quality is generally considered a luxury good, and since states at this stage of economic development have only limited resources available, environmental performance usually ranks far behind the demand for better economic conditions (Rouff 2009). However, once people attain a certain level of living standards, environmental quality turns into a normal public good and citizens demand that their government take actions to reduce or avoid pollution, for example, by enacting appropriate environmental regulations (Seldon and Song 1994). Figure 2 is a graphical representation of the EKC.

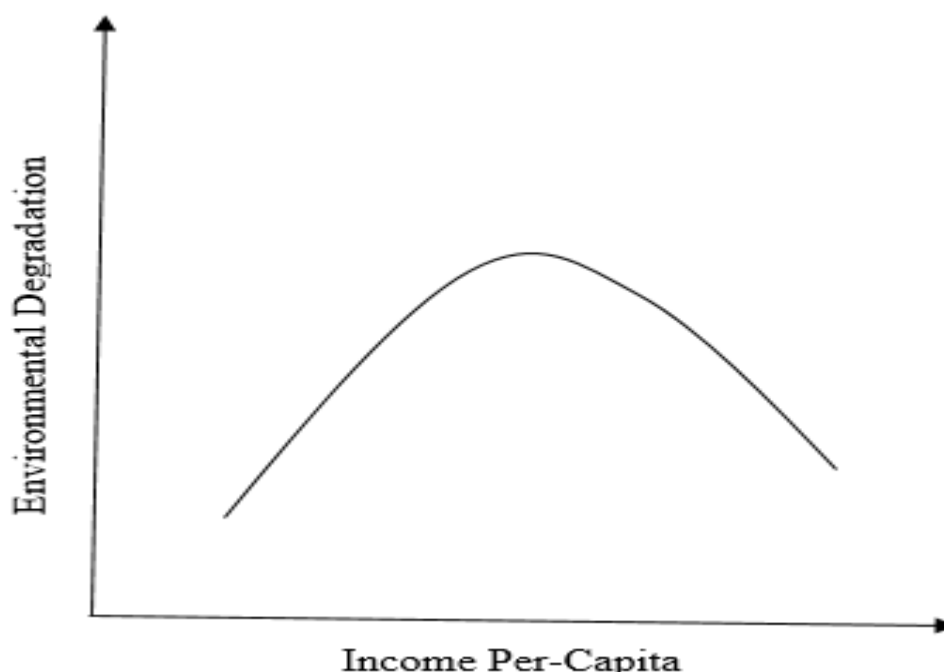


Figure 2. Environmental Kuznets Curve

The first set of empirical EKC studies appeared independently in three working papers: in a National Bureau of Economic Research (NBER) working paper as part of a study of the environmental impacts of North American Free Trade Agreement (NAFTA) (Grossman & Krueger 1991, 1994), the World Bank's 1992 World Development Report (Shafik & Bandyopadhyay, 1992) and a development discussion paper as part of a study for the International Labour Organisation (Panayotou, 1993).

Proponents of the EKC argue that relationship between economic growth and environmental quality follow an inverted-U shaped curve. Grossman and Krueger (1991), discovered, through an examination of air-quality measures in a cross-section of countries, that economic growth tends to alleviate pollution problems once a country's per capita income reaches about \$4,000 to \$5,000 US dollars. In another research work, apparently in response to concerns from alarmist cries of some environmental groups, Grossman and Krueger (1994) found that while increases in GDP may be associated with worsening environmental conditions in very poor countries, air and water quality appears to benefit from economic growth once some critical level of income has been reached.

In a separate study, Holtz-Eakin and Selden (1995) discovered the inverted U shape is consistent with a scenario in which industrial development initially leads to greater raw emissions of pollutants, but net emissions eventually decline as the increase in income associated with further development raises the demand for health and environmental quality. Further raising the issues of a trade-off between greenhouse gases and economic growth. Then, suggesting that faster growth could serve as part of the solution to worldwide emissions dilemma. Panayotou (1993) also gave further credence to the validity of the EKC, adding that environmental degradation overall (combined resource depletion and pollution) is worse at levels of income per capita under \$1,000. Between \$1,000 and \$3,000, both the economy and environmental degradation undergo dramatic structural change from rural to urban, from agricultural to industrial. A second structural transformation begins to take place as countries surpass a per capita income of \$10,000 and begin to shift from energy-intensive heavy industry into services and information-technology intensive industry. A reality application of shifts from scale effect to composition and technology effects.

These conclusions, however, creates an impression that economic growth and environment are not only not in conflict but the former is necessary to improve the latter (Ekins 2000). The most unequivocal expression to the argument in favour of the EKC suggests that as the development process picks up, when a certain level of income per capita is reached, economic growth turns from an enemy of the environment to a friend. Economic growth appears to be a powerful way of improving environmental quality in developing countries. If economic growth is good for the environment then policies that stimulate growth such as trade liberalisation, economic restructuring, and price reform ought also to be good for the environment. This, in turn, would tend to suggest that the environment needs no particular attention, either in terms of domestic environmental policy or international pressure or assistance, resources can best be focused on achieving rapid economic growth to move quickly through the environmentally unfavourable range of the Kuznets curve. (Panayotou, 1993).

The following are reviews of environment and income relationship for different environmental indicators from past studies;

Table 1. Results of past studies explaining the environmental quality-income relationships

Environmental Indicator	Researcher(S)	Turning Point (S) (\$)	Remark
CO ₂	Shafik & Bandyopadhyay (1992)	N.A ¹ .	Inconsistent with EKC
	Holtz-Eakin & Selden (1995)	35,400	Consistent with EKC
CO	Grossman (1993)	22,800	Consistent With EKC
	Selden & Song (1994)	6,200 & 19,100	Consistent With EKC
Dark Matter (Smoke)	Grossman & Krueger (1991)	5,000 & 10,000	N Shaped ²
	Grossman (1993)	4,700 And 10,000	N Shaped
SO ₂	Grossman & Krueger (1991)	4,100 And 14,000	N Shaped
	Shafik & Bandyopadhyay (1992)	3,700	Consistent with EKC
	Grossman (1993)	4,100 And 14,000	N Shaped
	Panayotou (1993)	3,000	Consistent with EKC

¹ Not Available

² A cubic function continuously rising in income with two turning points

	Selden & Song (1994)	8,900 And 10,700	Consistent with EKC
Suspended Particles Matter (SPM)	Grossman & Krueger (1991)	N.A.	Inconsistent with EKC
	Shafik & Bandyopadhyay (1992)	3,700	Consistent with EKC
	Grossman (1993)	16,000	Consistent with EKC
	Selden & Song (1994)	9,800 And 9,600	N Shaped
Dissolved Oxygen	Grossman & Krueger (1994)	2,703	Inconsistent with EKC
Fecal Coliform	Shafik & Bandyopadhyay (1992)	1,400 & 11,400	N Shaped
	Grossman (1993)	8,500	Consistent with EKC
	Grossman & Krueger (1994)	8,000	Consistent with EKC
Deforestation	Shafik & Bandyopadhyay (1992)	N.A.	Inconsistent with EKC
	Cropper & Griffiths (1994)	4,760	Consistent with EKC
	Cropper & Griffiths (1994)	5,420	Consistent with EKC
	Cg1994 Cropper & Griffiths (1994)	N.A.	Inconsistent with EKC
	Panayotou (1993)	823	Consistent with EKC
	Panayotou (1993)	1,200	Consistent with EKC

Table 1 presents the summary of results obtained from various investigations by more than one researcher at different times. While some results strongly reflect consistency with the EKC (Holtz-Eakin & Selden (1995), Selden & Song (1994), Grossman (1993)). Others find that after an improvement in environmental quality, the condition tends to deteriorate again at another turning point, causing an N shaped curve (Shafik & Bandyopadhyay (1992), and some other studies reveal contradictory results. Rather, they discover environmental pollutants to increase monotonically with income or fail to establish a relationship between environmental quality and income level clearly.

The inconsistencies in the results obtained from previous studies cast doubts on the robustness of the estimations in relation to the EKC, and it invites the question of how much reliance we can place on the data used. Stern *et al.* (1996) opine that data on environmental problems are notoriously patchy in coverage and/or poor in quality as well. After using data from the Global Environmental Monitoring Systems (GEMS)

of the World Health Organisation and the United Nations Environmental Programme, Grossman (1993) cautions that despite the intentions of the GEMS organisation, there may be reasons to suspect the representativeness of these data. Seldon and Song (1994) also shared the same view after using GEMS data on countries' aggregate emissions, constructed from estimates of fuel use. They remarked that: it is likely that emissions are measured only imperfectly, and that measurement errors for a given country persist across time. Panayotou (1993) used emissions rather than concentrations, but sparse data for developing countries required him to estimate their emissions using simplifying assumptions. Ekins (2000) cautions that there is little indication that the data problems are enough to cast doubts on the basic environment/income relationship estimations. However, it is important to note that inconsistencies in the results obtained are proof data integrity is a challenge.

The assumption of unidirectional causality from economic growth to environmental quality is considered another criticism of the EKC estimations. Arrow et al. (1995) note that all economic activity ultimately depends on the environmental resource base, imprudent use of which may irreversibly reduce the capacity for generating material production in the future. The environmental resource base includes assimilative capacities for waste discharges. Exceeding assimilative capacity gives rise to pollution, which in addition to being directly offensive or injurious to humans, can reduce the availability and productivity of renewable resources, and interfere with the operation of environmental life support. Therefore, Stern et al. (1994), considers that this bidirectionality of influence suggests that the economy and its environment are jointly determined (Perrings, 1987), and it is inappropriate to estimate a unidirectional causality from income to the environment.

Theoretical improvements have led to further criticisms of the EKC as a standard research tool to explain the relationship between economic activity and the environment. Stern (2004) suggest that some pollutants may decrease with income, however, other pollutants will increase instead such that there will be a composition change in pollution without a real overall reduction in emissions. Nordstroem & Vaughan (1999) also conclude that the EKC only holds for specific set of pollutants such as local air pollutants or some water pollutants but not for global air pollutants such as carbon dioxide (CO₂).

The fragility of the EKC is further supported by Hettige et al. (2000) using data on the water pollution intensity of different industry sectors, and they find no evidence for an EKC. Rather, they discover that pollution intensity rises until countries reach middle-income levels at which point pollution levels seem to stay constant. This agrees with the findings of Shen (2006) and Plassmann & Khanna (2006).

Similarly, Dasgupta et al. (2002) wrote a critical review of the EKC literature and other evidence on the connection between environmental quality and economic development in the *Journal of Economic Perspectives*. This article illustrates four alternative viewpoints for the EKC. There is the original EKC scenario which needs no further explanation. Another is the monotonicity of the EKC which in effect argues that while traditional pollutants might have followed the inverted U-shaped curve, the new pollutants that are replacing them do not. Such as carcinogenic chemicals, CO₂, etc. In other words, as the older pollutants are cleaned up, new ones emerge, so that overall environmental impact is not reduced. The third viewpoint is the 'race to the bottom' scenario, with a position that suggests that developed countries cut their emission levels by outsourcing their dirty production to developing countries. Now, developing countries will find it challenging to abate emissions due to the pressures of globalisation making them compromise environmental standards and regulations in the name of competitiveness and trade openness. Lastly, the revised EKC scenario does not reject the inverted U-shaped curve entirely; however, it suggests that the curve shifts downward and to the left over time due to technology improvement.

The current reality of the state of environmental quality of developed countries largely conflicts with the EKC hypothesis. Although, the Organisation for Economic Cooperation and Development (OECD) and the European Commission affirmed to have made progress in reducing some kind of air and water pollution and toxic chemical releases, it however still identifies substantial remaining problems from the unfinished agendas of the 1970s or 1980s across all areas of environmental concern, and points to the emergence of new problems, both from a change in substances of concern and the emergence of new sectors and industries with new kinds and degrees of pollution problems (OECD 1991a). The Commission of the European Communities (CEC), on its own part, also reported that some progress had been made towards reducing emissions of sulphur dioxide, suspended particulates, lead and

Chlorofluorocarbons (CFC) at the community level, but serious problems persist or are beginning to strongly emerge particularly with the greenhouse gases such as carbon dioxide, oxides of nitrogen atmospheric ozone and methane (CEC 1992c). Moreover, statistics reveal that The US and Europe were responsible for 23% of global CO₂ emission in 2007 and China has already surpassed the US at 21.5% of global CO₂ emission (International Energy Agency, 2009).

So from Beijing to Paris series of measures are being taken to reduce pollution efficiently. However, empirical studies have shown that part of the reduction in environmental degradation levels in the developed countries and increases in environmental degradation in middle-income and low-income countries may reflect this measures (Hettige, Lucas and Wheeler, 1992). For example, cars and electronic appliances banned from developed countries are exported to low income countries. And Hettige, Lucas, and Wheeler, 1992; Ekins, Folke and Constanza, (1994) further posits that environmental regulations in developed countries might further encourage polluting activities to gravitate toward developing countries.

This analysis is in contrast to the standard trade theory in Hecksher-Ohlin model, which suggests that an increase in trade would lead to a reduction in pollution for developing countries (low-income countries) since their comparative advantage lies in labour intensive production which emits less pollution. Hence, it is against this argument, that pollution haven hypothesis gains traction, suggesting that developing countries have a comparative advantage in pollution intensive industries because of their lax environmental regulations and consequently due to the composition and allocation effect of trade, dirty industries will settle in those countries with the laxest environmental regulations (Jaffe et al. 1995; Esty & Giraldin 1998; Stafford 2000) and countries with stricter environmental regulations will reap the gains of the effect of trade on pollution, which in most cases are high income countries.

2.3.2 The Commoner-Ehrlich Equation Model: A consumption-based approach

The EKC hypothesis advanced for describing environmental impact from economic activity in the previous section is purely production based, meaning, they are driven mainly by production activities of industrial organisations and nations. However, some

researchers have some philosophical issues with adopting a production-based approach to explain environmental problems. As Rees (1995), Daly (1996) and Duchin (1998) argue, “most environmental degradation can be traced to the behaviour of consumers either directly or indirectly, through activities like disposal of garbage, or the use of cars, or indirectly through the production activities undertaken to satisfy them.”

Ekins (1997) also argues against using production-based approaches for reasons being that “if the shift in production patterns has not been accompanied by a shift in consumption patterns two conclusions follow: (1) environmental effects due to the composition effect are being displaced from one country to another, rather than reduced; and (2) this means of reducing environmental impacts will not be available to the latest-development countries coming up behind them to which environmentally-intensive activities can be located”.

De Bruyn & Opschoor (1997) and Suri & Chapman (1998) have adopted the consumption-based approach to analyse the EKC hypothesis, and their findings reveal little evidence to support a conclusion of decreasing environmental impact at higher levels of income.

The relationship between environmental impact and human activity was initially expressed by Ehrlich and Holdren (1971) as;

$$I = PF \tag{1}$$

Where I = Environmental impact,

P = Population and

F = Impact per head.

Commoner (1971a: 175-6) later modified the relationship the following way: Pollutant emitted is a result of the product of three factors; – Population times the amount of a given economic good per capita times output of pollutant per unit of the economic

good produced'. Apparently, in agreement with the representation of Commoner (1971b: 37), Holdren and Ehrlich (1974: 288) later expressed the relationship as

$$I = PCT \quad (2)$$

Where P = Population,

C = Consumption per head and,

T = Impact per unit of consumption.

T in equation (2) refers to the Environmental Impact Coefficient (EIC), defined as the degree of impact caused by an increase of one unit of national income (Jacob 1991).

However, the validity of this model in explaining environmental impact have been challenged by the assumption that P, C, T are independent. Amalric (1995) doubts the validity of this assumption.

Understanding the relationship and interdependencies of these variables are of crucial importance because if there are interdependencies, the outcome of the application of this model could be complicated and challenging to explain reality. For instance, these interdependencies have the effect of magnifying the increase in 'I' for an increase in any of the other variables, i.e. 'I' will rise more than proportionately with the other variables (Ekins 2000). Another complicating factor connected with the Commoner-Ehrlich equation model is the possibility of heterogeneity within the P, C, T aggregates. Amalric (1995:94) reveals that, on the basis of a world level calculation, population growth seems to have contributed 64 percent of the growth of world CO₂ emissions from 1960-88. However, disaggregation of the population growth between developed and developing countries reduces the contribution to 41 percent, while that of developing countries alone falls to 17 percent. For this reason, Meadows (1995) considers the Commoner-Ehrlich equation model to be 'physically indisputable' but 'politically naïve'. However, Ekins (2000) cautions against dismissing the equation unnecessarily provided these interdependencies are taken into account when applying the model to real life cases.

2.3.2 Overlapping Generations Model of Growth and the Environment

Central to the cause of environmental problems is market failure. A condition where markets do not attain efficiency in resource allocation. A pure manifestation of market failure is in externalities. Externalities are situations where, because of market structure of property rights, relationship between economic agents are not all mediated through markets (Perman 2011), leading to situations where agents do not fully internalize the cost of their harmful actions, and thereby causing negative spillover effects.

Therefore, an alternative analytical framework to explain relationship between economic activities and the environment is an overlapping generation growth model. This model operates under the following assumptions; economic agents live in two periods, working while young and consuming while old, agents derive utility from consumption and environmental quality. If they consume, environment is degraded and choosing to invest improves the environment quality, in other words, actions of economic agents have consequences that far outlive them.

This model follows the overlapping-generations framework of Allais (1947), Samuelson (1958), and Diamond (1965). Furthermore, it has been applied in academic literatures by Kemp and Long (1980) and Mourmouras (1991) to analyse natural resource use, Mäler (1993) for the pricing of natural resource, and Sandler (1982) for the optimal provision and maintenance of club goods, such as national parks in a finite horizon economy. A proof that this model has general applicability beyond environmental quality.

However, applying this model within the context of economic growth and environmental quality, Jones and Manuelli (1995) posits an overlapping generations model in which economic growth is determined by market interactions and pollution regulations are set through collective decision making by the younger generation and therefore, depending on the decision-making institutions, the pollution income relationship can be an inverted-U, monotonically increasing, or even a 'sideways-mirrored-S shaped.

On the other hand, John and Pecchenino (1994) use the overlapping generation's model to argue that, relationship between income and pollution follows an inverted-V shape. An economy begins at a corner solution of zero environmental investment which translates to a simultaneous increase in environmental degradation and economic growth until a point at which positive environmental investment is desired when environmental quality will begin improving with economic growth (Andreoni and Levinson 2000). This position is consistent with the findings of Stokey (1998) and Jaeger (1998). Other theoretical contributions to this literature include Selden and Song (1995), who describe a variety of possible pollution-income paths in a dynamic growth model, Chaudhuri and Pfaff (1998b), who posit a particular mechanism, bundled commodities, to explain the EKC, and Kelly (1999), who focuses on the irreversible nature of many pollution problems as a driving force behind the curve. Each of these contributions has yielded different policy implications, which is a reflection of the complexity of this model.

What differentiates this model from the EKC analytical framework is the fact that overlapping-generations model takes into account externalities and the role of political and collective decision making in finding solutions to the problem of economic growth and environmental quality. And of course, this model does not support the EKC position that economic growth will automatically solve pollution problems. Rather, because of the need to preserve environmental quality for future generation and maintain pareto-improvement, environmental regulations are suggested to abate pollution by the planner as income increases.

From the literature reviews, one thing worthy of note is that using economic growth to explain the behaviour of environmental quality leads to faulty conclusions and therefore the EKC hypothesis can be deemed invalid (Ekins 2000).

The study of environmental quality appears to be a dynamic one warranting a need to enlarge the scope of analysis to have a better understanding of the variations. The Commoner-Ehrlich Equation gives us a clue as to the importance technology and economic structure plays in explaining variations in environmental quality. However, overlapping-generations model places less emphasis on variables that can be

quantified, instead introduces decision making variables such as policies and environmental regulations as factors that influence environmental quality positively.

The next chapter is dedicated to describing the research methods to be employed in carrying out the thesis.

3 Research Methods

This chapter contains method to be adopted in investigating this empirical research. The analysis consists of a quantitative panel data sets. This method allows to view the unobserved factors affecting a dependent variable and it does not assume that observations are independently distributed across time and they are beneficial for policy analysis purposes (Wooldridge 2013). Furthermore, the time component of our analysis makes it possible to investigate how changes in the independent variables (i.e., drivers of environmental impact) impact a country's environmental quality. Hence, panel data allows for a more robust analysis.

3.1 Drivers of environmental impact

The environmental impact of economic activity can be looked at in terms of extractions from or insertions into the environment. In either case and for any particular instance, the immediate determinants of the total impact are the size of the human population and the per capita impact (Perman et al., 2011). Per capita impact is a function of how much each individual produces or consumes, and on the technology employed in the production process.

3.2 Data Selection

Data set used for analysis consists of observations on 70 countries over a 16 year period beginning in 1998 and ending in 2013. Data sets were obtained from World Bank Databank catalogue. Also, Table (8) in the appendix shows the income classification of the country selected in the analysis as reported by World Bank Databank.

3.2.1 Dependent Variable

In the previous empirical literature on this topic, many different environmental indicators were used to proxy environmental quality such as air quality (Bernauer & Koubi 2009; Gassebner et al. 2006; Neumayer 2003a; Grossman & Krueger 1995), water quality (Gassebner et al. 2006; Sigman 2002) and the annual rate of deforestation (Shafik & Bandyopadhyay 1992 & Panayotou 1993). To effectively ensure that this

research reflects the recent trends and concerns in resource and environmental management, I decided to select air quality as a dependent variable. However, availability of comprehensive data that exists as balanced panel data sets limits choice of indicator used to carbon dioxide (CO₂) emissions, which is a greenhouse gas.

Carbon dioxide emissions used in this research are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, gas fuels and gas flaring. (World Bank 2017). Carbon dioxide emissions are the main contributor to global warming, and climate change since it accounts for a significant share of greenhouse gas emissions (World Bank 2017). To capture for size effect the natural log of CO₂ per capita is used in the model as the explained variable.

3.2.2 Independent Variables

The independent variables used for empirical analysis are as follows;

- GDP Per capita: To examine the effect of economic growth on environmental quality, the log of GDP per capita is included in the model. Using this variable is consistent with Environmental Kuznets Curve hypothesis and IPAT accounting identity model. According to Grossman and Krueger (1991), since environmental standards are often set at a national level, using country level GDP per capita (as opposed to national income) is arguably appropriate.
- Population density: Population is not included into the model because the dependent variable has been scaled by population to capture for size effect. Instead, people per square kilometer of land area, is included in the model. Including population density is consistent with past research by Selden and Song (1994).
- Technology: To capture technology effect, which is argued to improve environmental quality, energy intensity is used as a proxy. Energy intensity measures the energy required to produce a unit of economic value (IEA 2016).
- Trade Openness: Trade Openness is an important driver of economic activity which affects carbon emissions. A country's trade level is measured by the

yearly ratio of the sum of its export and imports scaled by a country's GDP to account for the size of the economy (Gleditsch 2002; Frankel 2003).

- Control Variables: In addition to the four independent variables, control variables which are suspected to be associated with environmental quality and the independent variables were included in the model. To assess for the effect of urbanisation and since a larger population consumes more natural resources, exhibits environmentally abusive behaviours and produces greater environmental degradation (Gassebner et al. 2006), we therefore include the share of urban population into the model. Furthermore, real growth rate is included to control for the fact that a growing economy is often associated with environmental degradation.

The following is a tabular description of variables considered for our empirical analysis and their source.

Table 2. Theoretical concepts and their indicators

Concept	Indicators	Data source
Environmental quality	Natural log of CO ₂ emissions per capita	World Bank (2017)
GDP per capita	Natural log of GDP per capita	World Bank (2017)
Population density	Natural log of population density	World Bank (2017)
Technology	Natural log of energy intensity	World Bank (2017)
Trade openness	Natural log of (import + export/ GDP)	World Bank (2017)
Urban population	Natural log of share of urban population	World Bank (2017)
Economic growth	Real GDP growth rate	World Bank (2017)

3.3 Regression model

Past studies on this subject have generally estimated an equation of the following general form:

$$f(E_{it}) = \alpha_0 + \alpha_1 g_1(Y_{it}) + \alpha_2 g_2(Y_{it}^2) + \alpha_3 g_3(Y_{it}^3) + \alpha_4 g_4(Y_{it-a}^n) + \beta \cdot B + \gamma t + \varepsilon_{it} \quad (3)$$

Where E_{it} = Environmental indicator for a country at time t

Y_{it} = Per capita income of a country at time t

Y_{it-a}^n = Polynomial of a lagged income

B = Vector of explanatory variables

Furthermore; α , β , γ are parameters to be estimated and $f(\cdot)$, $g(\cdot)$ are functional forms which are predominantly logarithmic or linear.

Following the identification of variables to be used in our empirical analysis, we specify our model as follows;

$$\begin{aligned} \ln\left(\frac{CO_2 \text{ emission}}{\text{capita}}\right)_{it} = & \alpha + \beta_1 \ln\left(\frac{GDP}{\text{capita}}\right)_{it} + \beta_2 \ln\left(\frac{GDP}{\text{capita}}\right)_{it}^2 + \beta_3 \ln\left(\frac{GDP}{\text{capita}}\right)_{it}^3 + \\ & \beta_4 \ln(\text{Pop. Density})_{it} + \beta_5 \ln(\text{Energy Intensity})_{it} + \\ & \beta_6 \text{Real growth rate}_{it} + \beta_7 \ln(\text{Urban Pop.})_{it} + \\ & \beta_8 \ln(\text{Trade Openness})_{it} + \mu_{it} \end{aligned} \quad (4)$$

4 RESULTS AND ANALYSIS

This chapter presents the results of the panel data Ordinary Least Square (OLS) regression model designed to answer my research questions. Which are; does economic growth have positive impact on environmental quality? Assess the validity of the inverted U curve model (EKC) in explaining the relationship between per capita GDP and the environmental indicator, which in this case is CO₂ emissions per capita.

Stata statistical software package was used to run the OLS regression estimations.

4.1 Estimation Method

To analyse the empirical result of the estimations, I use fixed effect estimation procedure. The reason for this choice is elaborated in detail below.

As captured in equation (3) and (4) in the previous chapter, fixed effect regression model includes time specific and country specific effect into the model. The merit this brings to our analysis is that it controls for variables that vary across countries but are constant over time such as cultural norms and for variables that vary over time but are constant across countries such as environmental legislations, energy prices, etc. (Stock and Watson 2012). In other words, it avoids omitted variable bias.

Rather than assuming a common intercept for all countries estimated, fixed effect estimates allow each country to have its own intercept (Beck 2001; Hsiao 2014; Wilson and Butler 2007). Instead of treating the country specific effect as a fixed effect, one could also treat the country specific effect as a random variable. Whenever the country specific effects are uncorrelated with the independent variables using random effect will yield an unbiased and more efficient estimation than fixed effects (Hsiao 2003). However, the result of the Hausman test (see Table 8) reports that p-value is significantly small in value and indicates that one of our models is inconsistent. This provides us with a sufficient basis to reject the random effect model in favour of fixed effects estimator.

On the other hand, the disadvantage of relying on fixed effects estimates is seen in the fact that it cannot be used to investigate time invariant variables as they become perfectly collinear with the country estimated, for instance, we cannot include a dummy variable in the model to measure whether a country is an oil exporter. However, in the case of slowly changing variables such as the political system of a country, using fixed effects leads in principle to unbiased estimates (Rouff 2009).

Finally, the inclusion of country and time specific effect in the panel data sets controls for exogenous shocks and absorbs the effects peculiar to each country. In other words, by adding time and country dummy variables, we are simply estimating the net effects of the regressors in Tables (4) and (6) on CO₂ emissions per capita and control for unobserved heterogeneity.

Therefore, with the inclusion of the combined country and time specific effects, our regression model is transformed to:

$$\begin{aligned} \ln\left(\frac{CO_2\text{emission}}{\text{capita}}\right)_{it} = & \beta_1 \ln\left(\frac{GDP}{\text{capita}}\right)_{it} + \beta_2 \ln\left(\frac{GDP}{\text{capita}}\right)_{it}^2 + \beta_3 \ln\left(\frac{GDP}{\text{capita}}\right)_{it}^3 + \\ & \beta_4 \ln(\text{Pop. Density})_{it} + \beta_5 \ln(\text{Energy Intensity})_{it} + \\ & \beta_6 \text{Real growth rate}_{it} + \beta_7 \ln(\text{Urban Pop.})_{it} + \\ & \beta_8 \ln(\text{Trade Openness})_{it} + \alpha_i + \gamma_t + \mu_{it} \end{aligned} \quad (5)$$

Where α_i = Country specific effects

γ_t = Time specific effects.

β = Estimated coefficients

μ_{it} = Error terms

Results reported in Tables (5) and (7) reflect this transformation after using a two-way fixed effects estimation model.

4.2 Empirical Analysis

Before we proceed to the empirical analysis, a descriptive statistics and correlation matrix of the independent variables are reported in Tables (3) and (4) respectively. All in natural logarithm form except GDP growth rate.

Table 3. Descriptive statistics – sample: all countries

Variables	Mean	Median	Std. Deviation	Minimum	Maximum	Observations
CO ₂ per capita ³	0.2273	0.5867	1.824079	-4.0800	3.4534	1120
GDPPC	7.806	7.688	1.626171	4.664	11.122	1120
GDPPC ²	63.57	59.11	26.26833	21.75	123.70	1120
GDPPC ³	538.7	454.4	329.7204	101.4	1375.8	1120
Population density	4.1539	4.3456	1.296894	0.8902	7.4688	1120
Energy intensity	1.7725	1.7210	0.485951	0.6473	3.5247	1120
GDP growth rate	4.076	4.184	4.261989	-36.700	33.736	1120
Percentage share of urban population	3.842	3.979	0.5558639	2.058	4.588	1120
Trade openness	4.033	4.089	0.6861768	0.000	5.246	1120

In assessing the degree of the relationship between the independent variables, Table (4), reports the correlation coefficients. GDP per capita has weak negative correlation with population density, energy intensity and real growth rate. While, in contrast, it indicates a positive correlation with urban population and trade openness.

Furthermore, an assessment of the correlation between CO₂ emissions per capita and the independent variables as depicted by scatterplots (See Appendix), show a strong positive correlation between CO₂ emissions and GDP per capita and share of urban population but a weak positive correlation with trade openness (See Figures 3, 7 and 8 respectively). On the other hand, Figures (4), (5), (6) fail to establish a clear direction

³ Measured in metric tons per capita

of relationship between population density, energy intensity, real growth rate and CO₂ emissions.

Table 4. Correlation matrix of Independent variables (1998-2013)

	GDPPC	GDPPC ²	GDPPC ³	Pop. Density	Energy Intensity	Growth rate	Urban Pop.	Trade Openness
GDPPC	1.0000	0.9950	0.9817	-0.0736	-0.3662	-0.1890	0.8135	0.1808
GDPPC ²	0.9950	1.0000	0.9957	-0.0652	-0.3305	-0.2022	0.7797	0.1529
GDPPC ³	0.9817	0.9957	1.0000	-0.0566	-0.2959	-0.2122	0.7423	0.1279
Pop. Density	-0.0736	-0.0652	-0.0566	1.0000	0.0778	0.0471	-0.2187	-0.0087
Energy Intensity	-0.3662	-0.3305	-0.2959	0.0778	1.0000	0.0353	-0.3588	-0.1898
Growth rate	-0.1890	-0.2022	-0.2122	0.0471	0.0353	1.0000	-0.2078	0.02770
Urban Pop.	0.8135	0.7797	0.7423	-0.2187	-0.3588	-0.2078	1.0000	0.2076
Trade Openness	0.1808	0.1529	0.1279	-0.0087	-0.1898	0.0277	0.2076	1.0000

Making extrapolations on the basis of correlations is misleading and hence we cannot infer a cause and effect relationship. To overcome this limitation, we report our fixed effect regression coefficient estimates in Table (5) and perform further statistical tests to assess the statistical significance.

Going further, to report robust estimations, different regressions were carried out, including separate regressions for high, middle and low-income countries (see Table 7 and country list in Appendix).

Since the dependent variable is CO₂ emissions per capita, a positive coefficient sign implies an increase in emissions and negative coefficient sign implies decrease in emissions. Furthermore, considering the dependent variable was expressed in natural log form, the coefficients have a percentage interpretation (Wooldridge 2013).

Table 5. Different estimators of CO₂ Emissions⁴

Dependent variable : ln (CO ₂)emission per capita					
Independent variables	(1)	(2)	(3)	(4)	(5)
ln (GDPPC)	0.349289*** (0.022399)	0.9622808*** (0.0679542)	-1.1379883** (0.3606244)	-0.9096820** (0.3365943)	-1.3067516*** (0.3526436)
ln(GDPPC ²)		-0.0414216*** (0.0043563)	0.2139822*** (0.0446019)	0.1879250*** (0.0419421)	0.2335965*** (0.0437568)
ln (GDPPC ³)			-0.0103055*** (0.0018483)	-0.0093400*** (0.0017573)	-0.0113014*** (0.0018106)
ln(population density)	0.347765*** (0.075521)	0.0334157 (0.0796318)	0.1247185 (0.0832952)		0.0331108 (0.0720246)
ln(energy intensity)	0.247531*** (0.039524)	0.3264298*** (0.0388111)	0.2768252*** (0.0391674)	0.2895566*** (0.0385521)	0.2732989*** (0.0385764)
Real growth rate			0.0014927 (0.0012404)		0.0017604 (0.0011428)
ln(urban population)			0.3874765*** (0.0987210)	0.4017905*** (0.0975688)	0.3316586*** (0.0951220)
ln(trade openness)	0.069260*** (0.013219)	0.0571736*** (0.0127445)	0.0648310*** (0.0127724)	0.0647680*** (0.0126848)	0.0627952*** (0.0126406)
Country specific effects	Yes	Yes	Yes	Yes	Yes
Time specific effects	Yes	Yes	Yes	Yes	No
R ²	0.3811	0.4311	0.4554	0.4533	0.44766
Time	16	16	16	16	16
Observations	1120	1120	1120	1120	1120
No. Countries	70	70	70	70	70

⁴ Panel standard errors in parenthesis

Significant levels: * = 5% significant level, ** = 1% significant level, *** = 0.1% significant level

The result of the estimations are summarised in Table (5). Each column reports a different regression estimate, and each row reports coefficient estimates, standard errors, and other relevant information about the regression.

Column (1) in Table (5) reports initial regression including explanatory variables that are considered drivers of environmental impact. All coefficients were positive and statistically significant, implying they are all associated with increases in CO₂ emissions.

The regression in Column (2) included the square of GDP per capita. Including this additional explanatory variable transforms the model to align with the logic of the EKC and the result reported for the estimated coefficients are statistically significant. This suggests that the relationship between CO₂ emission and GDP per capita is non-linear. Some episodes of increased CO₂ emissions are followed by a turning point where emissions begin to reduce. However, we will subject this to further statistical tests in the next section to assess the statistical significance.

The baseline model, reported in column (3), includes all the variables specified in Equation (4). Population density is not statistically significant, likewise real growth rate. However, the R² value increased, indicating the included additional variables fit the model. In column (4), the statistically insignificant variables were dropped, but coefficients of independent variables left behind did not change substantially.

Column (5) reports the regression estimates without controlling for the time specific effect. It is a fairly common practice in research to report and compare estimates for one way fixed effect, which includes only country specific effect, and two ways effect estimations for the sake of reporting robust analysis and determining which effect accounts for greater variations in the dependent variable. Comparing columns (3) and (5), we can deduce that two ways fixed effect model explains greater variations in CO₂ emissions during the period studied. Hence, we drop the use of one way fixed effect model in subsequent estimations.

4.2.1 Statistical test for significance of regression model and EKC hypothesis

Since one of the research objective of this thesis is to assess the validity of the EKC hypothesis, we employ joint F statistics to justify the inclusion GDP per capita and its transformations in the regression model and also determine the overall significance of our regression model in Table (5) in explaining the variance of CO₂ emissions.

The F statistics is often useful for testing exclusion of a group of variables when the variables in the group are suspected to be highly correlated (Wooldridge 2013). To perform this test, we compare two models per time and classify each model as a restricted model, for the one with fewer variables, and unrestricted model for the full model.

For this test GDP per capita, its square and cubic transformations will be excluded in the restricted models.

To model the EKC hypothesis previous researchers like Grossman and Krueger (1994), Shafik and Bandyopadhyay (1992), Seldon and Song (1994), and Panayotou (1993) have employed either a quadratic function or cubic functions to establish an inverted U relationship between environmental indicators and income per capita. For the sake of our analysis, we proxy income per capita with GDP per capita. This statistical test will help us justify the inclusion of GDP per capita and its transformations.

We test each result reported against the stated null and alternative hypothesis, which are as follows;

$$H_0 = \beta_1 = \beta_2 = \beta_3 = 0$$

Null hypothesis: Restricted model is statistically better than unrestricted model

Alternative hypothesis: Unrestricted model is significantly better.

To guide our judgement, we reject the null hypothesis whenever we have small p-values (Wooldridge 2013).

The following table contain the result of the joint F statistics tests of regressions in Table (5).

Table 6. Results of F statistic tests

F test	Restricted Variables	F-Value	P-Value	Remark
Column 2	GDPPC, GDPPC ²	177.34	0.0000	Reject null hypothesis
Column 3	GDPPC, GDPPC ² , GDPPC ³	103.53	0.0000	Reject null hypothesis
Column 4	GDPPC, GDPPC ² , GDPPC ³	107.85	0.0000	Reject null hypothesis
Column 5	GDPPC, GDPPC ² , GDPPC ³	117.29	0.0000	Reject null hypothesis

In each test carried out we reject the null hypothesis because of the extremely small p-values reported. The implications are; first, the included variables significantly improves the fit of our regression model in explaining the variation in CO₂ emissions. Secondly, it justifies the addition of GDP per capita, the square and cubic transformations in the model. Finally, there is a non-linear relationship between the environmental indicator and GDP per capita

4.2.2 Discussion of Regression Results

From our result reported in Table (5) and the further test carried out we can infer that the relationship between CO₂ emissions and GDP per capita is non-linear. This somewhat reflects the EKC hypothesis, however not entirely. The reason for this position will be elaborated on later.

The cubic transformation of GDP per capita in column (3) and (4) suggests that emission is decreasing with continuous incomes, on an aggregate level. This is statistically significant at the 0.1% level. A visual representation of this relationship is displayed in the scatter plot (see appendix). The fitted linear, quadratic and cubic relationship are represented with the red, blue and green lines respectively. Thus, we

can infer that GDP per capita slightly contributes to CO₂ emission reduction because the cubic coefficients are somewhat close to zero.

On the contrary, the other economic variables considered were associated with increase in CO₂ emissions. Columns (1) through (4) consistently reported energy intensity and trade openness contributed to emissions, statistically significant at the 0.1% level. Population density was also reported to be associated with CO₂ emission increase, however, it was evidently not statistically significant.

The control variables included in the regression models reported mixed results. Share of urban population contributed to increase in CO₂ emissions. Statistically significant at the 0.1% significant level. On other hand, contribution of real growth rate was not statistically significant.

The estimations reported in Table (5) were for the aggregate panel data, however, to allow for more robust analysis we disaggregate the data and include separate regression estimates for high, middle and low income countries in Table (7).

Table 7. Different estimators of CO₂ emissions for high, middle and low income countries⁵

Dependent variable: CO ₂ emission per capita			
Independent variables	High income	Middle income	Low income
ln GDPPC	10.3552705* (4.6076384)	-0.3406544 (1.0019154)	-12.079949*** (2.7793674)
ln GDPPC ²	-1.0313810* (0.4757871)	0.1312143 (0.1320995)	1.9806612*** (0.444398)
ln GDPPC ³	0.0347059* (0.0162814)	-0.0079455 (0.0057729)	-0.1028051*** (0.0233831)

⁵ Panel standard errors in parenthesis

Significant levels: * = 5% significant level, ** = 1% significant level, *** = 0.1% significant level

ln population density	-0.0528360 (0.0646498)	-0.2507337 (0.1308183)	1.2457372** (0.3823503)
ln energy intensity	0.8407648*** (0.0815462)	0.5555759*** (0.0631019)	0.2612028** (0.0873597)
Real growth rate	0.0073219*** (0.0019837)	0.0034520* (0.0015527)	-0.0010722 (0.0029152)
ln urban population	0.8050996* (0.3311631)	0.5362345*** (0.1241396)	0.0014427 (0.2105222)
ln trade openness	0.1369222* (0.0565142)	0.0667978*** (0.0139784)	0.0641286 (0.0336772)
Country specific effects	Yes	Yes	Yes
Time specific effects	Yes	Yes	Yes
R ²	0.6131	0.6143	0.4212
Time	16	16	16
Observations	256	592	272
No. of countries	16	37	17

The result reported in Table (7) show that GDP per capita is associated with an increase in CO₂ emissions for high income countries. Statistically significant at the 5% level. On the contrary, the GDP per capita transformations for middle and low incomes countries reports emission falling, rising and falling. The cubic transformation reports that emission is somewhat reducing. However, these results are sensitive to sample with regards to sample sizes. When looking at the middles income countries, estimations reported were not statistically significant.

The effect of energy intensity of the estimation reports a positive relationship in all the income classifications. Statistically significant at the 0.1% level for high and middle income countries and the 1% level for low income countries. Suggesting that an increase in energy intensity is associated with increase in CO₂ emissions. We can deduce that the effect of technology advancement is yet to translate significantly to CO₂ emissions reduction.

Turning to the effect of trade openness, we find that trade openness contributed to increase in CO₂ emissions. The effect was same throughout the three income classifications. However, the result was not statistically significant for low income countries. We can deduce that the scale effect of high trade volumes of high and middle income countries induced CO₂ emissions.

The result reported for population density was not statistically significant for high and middle income countries but statistically significant for low income countries which was found to be associated with increase in CO₂ emissions. However, the share of urban population was associated with increases in CO₂ emissions across all the income classifications but the estimate was not statistically significant for low income countries.

Finally, the effect of real growth rate is associated with a marginal increase in CO₂ emissions, the result reported was statistically significant for high and middle income countries and not significant for low income countries.

The R² value reported for estimations were 61.3%, 61.4% and 42.1% for high, middle and low income countries respectively. This effectively represent the degree to which the independent variables explain the variations in CO₂ emissions in the respective country income classifications.

4.3 Summary of findings

In this section we compare the results reported with previous research in this field and share further insight into our empirical results.

The objective of this thesis was to examine the impact of economic growth on environmental quality, using relevant economic and environmental indicators that have considerable explanatory powers and strictly aligns with economic theory.

The strength of our analysis is rooted in the inclusion of country specific and time specific fixed effects to mitigate the threat of omitted variable bias. Following the result reported in Table (5), we find that country and time specific effects significantly

explains variations in the increase of CO₂ emissions. Thus, we can deduce that factors that are country specific, such as weather condition, contributed to increased emissions. For example, countries experiencing prolonged cold weather season will consume more energy which will significantly increase their carbon footprint and induce emissions. On the other hand, time specific factor such as compliance with environmental policy requirements or absence effective policy and the trend of oil price movements are variables that could have contributed to variations in CO₂ emissions.

The cubic and quadratic transformation in our regression suggests that GDP per capita significantly had a non-linear effect on CO₂ emissions. We can infer that periods of increased emissions were followed by reduced emissions. This was statistically significant on an aggregate level. Furthermore, the non-linearity in relationship somewhat agrees with the EKC hypothesis, however, following the estimations reported for high, middle and low income countries, the cubic transformation reports an increase in CO₂ emissions for high income countries. This finding is contrary to the EKC hypothesis which posits that rich countries have reached the environmental turning point which is characterized by reduced emissions and by extension, improved environmental quality. Our result for high income countries was statistically significant and consistent with some findings of De Bruyn and Opschoor (1997) and European Environmental Agency (1995), which consider air pollutants as a threat to environmental quality for high income countries going into the future.

Share of urban population is reported to have contributed to CO₂ emissions. This result was significant statistically. It is consistent with findings of Rouff (2009). This position finds logical expression in the fact that the cities are economic nerve center of every country as measured by the number of cars and industries and their operations significantly contribute to diminishing environmental quality.

The contribution of energy intensity to CO₂ emission as reported in our results is also important to note. Increased CO₂ emissions explained by energy intensity was stronger in high income countries compared to middle income countries and the estimation for low income countries was not statistically significant (see Table 7). We suggest this is possibly due to the industrial processes and structure of high income countries. An

implication of this result according to studies reported by Hettige *et al.* (1992) and Lucas *et al.* (1992) is that there is no EKC for toxic pollution; because manufacturing output increases with total output, although at a decreasing rate, so does the absolute amount of pollution generated.

Finally, our findings on trade openness reveal there is a positive relationship with CO₂ emissions. In other words, it contributed to increased CO₂ emissions in the countries examined. This result is consistent with findings of Rouff (2009), Nasir and Rehman (2011) and Shahzad *et al.*, (2017). According to theory, the net effect of trade openness on environmental quality is ambiguous. Standard trade theory argues on the basis of comparative advantages i.e. net effect of trade openness should increase pollution for high income countries and reduce pollution for low income countries while pollution haven hypothesis, on the other hand, argues reduced pollution for high income countries due to strict environmental regulations and increased pollution for low income countries due to lax environmental regulations.

Considering trade activity is a major driver of economic growth, we can deduce that, the CO₂ emissions increasing effect of trade openness reported in Tables (5) and (7) is as a result of scale effect and ineffective policies towards the operations of polluting industries.

5 POLICY RECOMMENDATIONS AND CONCLUSIONS

In this chapter we consider some policy implication of the results presented in chapter 4 and make final submissions based on the empirical study.

5.1 Policy Recommendations

The findings in this empirical study yields certain implications in the area of public policy to ensure sound environmental quality and performance. The results reported reflects strong need to ensure effective policy design of economic variables which influences environmental quality. This justifies our use of fixed effect estimation model because it is a much more convincing econometric tool for policy analysis when using aggregated data (Wooldridge 2013).

Non-linearity of the relationship between GDP per capita and CO₂ emission, indicates episodes of reduced emissions can be quickly followed by rise in emissions and vice-versa. This indicates how volatile and unstable environmental issues can be. Hence, effective policies and regulations are suggested to be in place to guide economic activities of trade, energy supply, etc. which are significant drivers of environmental quality. This position is consistent with the submissions of the overlapping generations' model, which posits that economic growth will not automatically translate to environmental improvement unless there are advancements in social institutions that are essential to enforce environmental regulation (Dasgupta et al., 2001b). The following are recommendations considered highly vital in this regard.

- Regulations: According to Hettige et al., (2000a), pollution grows unless environmental regulation is strengthened. For instance, regulations that ensure international trade agreements do not violate emission standards, and where regulatory compliance are rewarded and non-compliance are punished. A strong and robust institution plays a vital role in enforcing regulation.
- Property right: This is an economic instrument which is market based. It allows individuals to have greater incentive to manage, conserve, and to accumulate wealth that can be traded or passed to future generations (Dinda, 2004). Economic progress in this regards is determined partly by the extent to which

environmental assets are protected by private property rights (Chichilinsky, 1994; Lopez, 1994). Furthermore, countries with a high degree of private ownership and property allocation of property rights have more efficient resource allocation, which help to increase income and decrease environmental problems (Cropper and Griffiths, 1994). This will particularly be of importance in the location of polluting industries.

- Carbon Tax: Top among the cause of environmental pollution is market failure. Carbon tax is an effective means to correct this, however, in reality it is considered a political dead end. Applying the principle of double dividend hypothesis (Tullock, 1967) could see future acceptance of carbon tax achieve dual benefit of increased revenues for government to execute emission reduction initiatives and help businesses come up with cost efficient and effective technology based solutions to emission.

5.2. Conclusion

The results presented in chapter 4 have been able to effectively provide answers to our research questions. Increase in GDP per capita, which was our proxy for economic growth, had significant effect on CO₂ emissions. Employing the joint F statistics test, we established a non-linear relationship between environmental quality and GDP per capita. Results reported from our aggregate panel data suggest marginal decline in emission levels after episodes of increased emissions. However, this finding is a reflection of the volatility of environmental pollution which requires careful handling and effective management. Placing reliance on the EKC to explain the relationship between environmental quality and economic growth could lead to misguided judgements. Instead, timely policy responses that reflect current environmental reality and economic trends are strongly recommended.

We acknowledge that country and time specific effects played a significant part in explaining the variations of CO₂ emissions in our results. These effects could range from climatic conditions, unpredictable oil price movements, geography of a country that would necessitate use of road transportation which burns more fossil fuels and cultural behaviours that either promote or reduce environmental abuse.

On the basis of our findings, we could argue for an increased need to focus more on the technology effect of economic growth to neutralize the scale effect. This would require more investment in education and research into cutting edge technologies that are affordable and available on a large scale. The implication would be discovery of more end-of-pipe solutions, cleaner forms of production methods and design of policies that reward these ingenuity and efforts. This would significantly reduce pollution levels.

By categorizing the countries into three income groups as defined by World Bank, we were able to statistically examine results reported for high income countries. Middle and low income countries, on the other hand, reported mixed significant levels. We suspect the results reported are sensitive to sample sizes which might not be a reflection of the entire population. Focusing analysis only on middle and low income countries would be considered in future research.

Further limitation of this thesis bordered on the inability to include data on other environmental indicators such as other forms of air quality, water quality and deforestation. Doing this could provide for more robust analysis. However, cross sectional and time series data on these environmental indicators are patchy in coverage. This is an aspect identified for future research improvement.

Finally, research in the area of environmental resource management and sustainable development is going to receive increased interest in the future because of the need to ensure the Paris climate agreement becomes a reality and the next generation meets a livable environment.

REFERENCES

- Allais, M. (1947). *Economie et Interet*. Paris: Imperimerie Nationale.
- Andreoni, J. & Levinson, A. (2001). The simple analytics of the environmental Kuznets curve. *Journal of Public Economics*, 80(2), 269-286.
- Arrow, K., Bollin, B., Constanza, R., Dasgupta, P., Folke, C., Holling, C., Jansson, B., Levin, S., Mäler, K., Perrings, C. & Pimental, D. (1995). Economic growth, Carrying Capacity, and The Environment. *Science*, 268, 520-521.
- Barkley, P. & Seckler, D. (1972). *Economic growth and environmental decay: the solution becomes the problem*, Harcourt Brace Jovanovich.
- Beck, N. (2001). Time-Series–Cross-Section Data: What Have We Learned in the Past Few Years? *Annual Review of Political Science*, 4(1), 271-293.
- Brown, L., Durning, A., Flavin, C., French, H., Jacobson, J., Lenssen, N., Lowe, M., Postel, S., Renner, M., Starke, L., Weber, P. & Young, J. (1993). *State of the World 1993*. London: Earthscan, 4-5.
- CEC (Commission of the European Communities) 1992c. *The State of the Environment in the European Community: Overview*, COM (92) 23 – Vol. III, March, CEC, Brussels.
- Chichilnisky, G. (1994). North-South Trade, Property Rights, and the Dynamics of the Environment. *SSRN Electronic Journal*.
- Commoner, B. (1971a) *The Closing Circle: Confronting the Environmental Crisis*, Jonathan Cape, London.
- Commoner, B. (1971b) ‘The Environmental Cost of Economic Growth’ in Schurr, S. Ed *Energy, Economic Growth and the Environment*, John Hopkins University Press, Baltimore/London: 30-65
- Cropper, M. & Griffiths, C. (1994). The Interaction of Population Growth and Environmental Quality. *American Economic Review Papers and Proceedings*, 84(2), 250-4.
- Daly, H., (1996). Consumption: value added, physical transformation and welfare. In: Constanza, R., Segura, O., Martinez-Alier, J. (Eds.), *Getting Down to Earth: Practical Applications of Ecological Economics*. Island Press, Washington, DC, 44-59

- Dasgupta, S., Laplante, B., Wang, H. & Wheeler, D. (2002). Confronting the Environmental Kuznets Curve. *Journal of Economic Perspectives*, 16(1), 147-168.
- Dasgupta, S., Mody, A., Roy, S. & Wheeler, D. (2001b). Environmental Regulation and Development: A Cross-country Empirical Analysis. *Oxford Development Studies*, 29(2), 173-187.
- De Bruyn, S.M., & Opschoor, J.B., (1997). *Developments in the throughput-income relationship: theoretical and empirical observations*. *Ecol. Econ.* 20, 255-270.
- Diamond, P. (1965). 'National debt in a neoclassical growth model.' *American Economic Review*, Vol.55, 1126-50
- Dinda, S. (2001). A note on global EKC in case of CO₂ emission. Economic Research Unit, Indian Statistical Institute, Kolkata. Mimeo.
- Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics*, 49(4), 431-455.
- Duchin, F. (1998). *Structural economics*. Washington, D.C.: Island Press.
- Economist.com. (2013). [online] Available at: <https://www.economist.com/news/briefing/21583245-china-worlds-worst-polluter-largest-investor-green-energy-its-rise-will-have> [Accessed 18 Mar. 2017].
- Ehrlich, P.R & Holdren, J.P (1971) Impact of population growth, *Science* 171, 1212-1217
- Ekins, P. (1997). The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence. *Environment and Planning A*, 29(5), 805-830.
- Ekins, P. (2000). *Economic growth and environmental sustainability: The Prospects for Green Growth*. London; New York: Routledge.
- Ekins, P., Folke, C. & Costanza, R. (1994). Trade, environment and development: the issues in perspective. *Ecological Economics*, 9(1), 1-12.
- Esty, D. C. & Girardin, D. (1998), 'Environmental Protection and International Competitiveness: A Conceptual Framework', *Journal of World trade* 32(3), 5-46.
- Frankel, J. A. (2003), 'The Environment and Globalisation', *NBER Working Paper No. W10090*.

- Gassebner, M., Lamla, M. L & Sturm, J. E (2006), 'Economic, Demographic and Political Determinants of Pollution Reassured: A sensitivity Analysis', *CESifo Working Paper No. 1699*.
- Gleditsch, K. S. (2002), 'Expanded Trade and GDP Data', *Journal of Conflict Resolution* 46(5), 712-724.
- Grossman, G. (1993) '*Pollution and Growth: What Do We Know?*', CEPR Discussion Paper No. 848, October, Centre for Economic Policy Research, London
- Grossman, G. & Krueger, A. (1991). 'Environmental Impacts of a North American Free Trade Agreement', NBER Working Paper No. 3914, November, National Bureau of Economic Research, Cambridge, MA.
- Grossman, G. & Krueger, A. (1994). Environmental impacts of a North American Free Trade Agreement. *The US-Mexico Free Trade Agreement*.
- Grossman, G. M. & A. B. Krueger, (1995). "Economic growth and the environment," *Quarterly Journal of Economics*, Vol.112. 353-378
- Hettige, H., Dasgupta, S. & Wheeler, D. (2000a). What improves environmental compliance? Evidence from Mexican industry. *Journal of Environmental Economics and Management*, 39(1), 39-66.
- Hettige, H., Lucas, R. & Wheeler, D. (1992). The toxic intensity of industrial production: Global patterns, trends, and trade policy. *American Economic Review*, 82(2), 478-481.
- Hettige, H., Mani, M. & Wheeler, D. (2000). Industrial pollution in economic development: the Environmental Kuznets Curve revisited. *Journal of Development Economics*, 62(2), 445-476.
- Holdren, J. & Ehrlich, P. (1974) 'Human Population and the Global Environment', *American Scientist*, Vol. 62 (May-June), 282-92.
- Holtz-Eakin, D. & Selden, T. (1995). Stoking the fires? CO₂ emissions and economic growth. *Journal of Public Economics*, 57(1), 85-101.
- Hsiao, C. (2014). *Analysis of panel data*. Cambridge: Cambridge University Press.
- International Energy Agency, (2009). *Key World Energy Statistics*. Paris: International Energy Agency. Available at: http://www.iea.org/textbase/nppdf/free/2009/key_stats_2009.pdf.

- Jacobs, M. (1991). *The Green Economy*, Pluto Press, London.
- Jaffe, A., Peterson, S. R., Portney, P. R. & Stavins, R. N (1995), 'Environmental Regulation and the Competitive ness of U.S. Manufacturing: What Does the Evidence Tell Us?', *Journal of Economic Literature* 33, 132-163.
- John, A. & Pecchenino, R. (1994). An Overlapping Generations Model of Growth and the Environment. *The Economic Journal*, 104(427), 1393.
- Jones, L. E., Manuelli, R.E., (1995). A positive model of growth and pollution controls. *NBER, working paper*.
- Kato, K. (1998). Grow Now, Clean Up Later? The Japanese Experience. In: W. Cruz, K. Teakemoto and J. Warford, ed., *Urban and Industrial Management in Developing Countries. Lessons from Japanese Experience*. Washington D.C: The World Bank, 41-44.
- Kemp, M. & Long, N. (1980). 'The underexploitation of natural resources: a model with overlapping generations.' In *Exhaustible Resources, Optimality and Trade* (ed. M. Kemp and N. Long). Amsterdam: North Holland.
- Krueger, A. (1991). [Growth, Macroeconomics, and Development]: Comments. *NBER Macroeconomics Annual*, 6, 364.
- Kuznets, S., "Economic growth and income inequality, *American Economic Review*, Vol. 49 (1955). 1-28.
- López, R. (1994). The Environment as a Factor of Production: The Effects of Economic Growth and Trade Liberalization. *Journal of Environmental Economics and Management*, 27(2), 163-184.
- Lucas, R., Wheeler, D. & Hettige, H. (1992). 'Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution: 1960-88' in Low, P. Ed. *International Trade and the Environment*, World Bank Discussion Paper No. 159, World Bank, Washington, DC, 67-86
- Mill, J. S (1904). *Principles of Political Economy with Some of their Applications to Social Philosophy*. 6th ed. London: Longmans, Green & Co, 454.
- Mourmouras, A. (1991). Competitive Equilibria and Sustainable Growth in a Life-Cycle Model with Natural Resources. *The Scandinavian Journal of Economics*, 93(4), 585.
- Mäler, K. G. (1993). 'Economic growth and the environment.' Beijer International Institute of Ecological Economics Discussion Paper Series No. 25.

- Nasir, M., & Ur Rehman, F. (2011). Environmental Kuznets Curve for carbon emissions in Pakistan: An empirical investigation. *Energy Policy*, 39(3), 1857-1864.
- Nordstroem, H., & Vaughan, S. (1999), 'Trade and Environment', Special Studies 4. Geneva: World Trade Organisation.
- OECD (Organisation for Economic Cooperation and Development) (1991a). *The State of the Environment*, OECD, Paris.
- Panayotou, T., "Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development." Working Paper WEP 2-22/WP238, Technology and Employment Programme (Geneva: International Labor Office, 1993).
- PBL Netherland Environmental Assessment Agency (2017). *Trends in global CO₂ and total greenhouse gas emissions*. The Hague: PBL Netherland Environmental Assessment Agency, 6.
- Perman, R., Ma, Y., Common, M., Maddison, D. & MacGilvray, J. (2011). *Natural resource and environmental economics*. Harlow, England: Addison-Wesley.
- Perrings, C. A., (1987) *Economy and Environment: A Theoretical Essay on the Interdependence of Economic and Environmental Systems*. Cambridge: Cambridge University Press.
- Plassmann, F. & Khanna, N. (2006). Household Income and Pollution. *The Journal of Environment & Development*, 15(1), 22-41.
- Rees, W. (1995). *Reducing the Ecological Footprint of Consumption. The Workshop on Policy Measures for Changing Consumption Patterns*. Seoul, South Korea.
- Roberts, J. & Grimes, P. (1997). Carbon intensity and economic development 1962–1991: A brief exploration of the environmental Kuznets curve. *World Development*, 25(2), 191-198.
- Rouff, G. (2009). *Grow Rich and Clean Up Later? Joint Effects of International Integration and Democracy on Environmental Quality in Developing Countries*. Ph.D. ETH Zurich.
- Samuelson, P. (1958). An Exact Consumption-Loan Model of Interest with or without the Social Contrivance of Money. *Journal of Political Economy*, 66(6), 467-482.
- Schwab, K. (2017). *Fourth Industrial Revolution*. The Crown Publishing Group.

- Selden, T. & Song, D. (1994). Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions? *Journal of Environmental Economics and Management*, 27(2), 147-162.
- Shafik, N. & S. Bandyopadhyay, (1992) "Economic growth and environmental quality: time series and cross-country evidence," *Background Paper for the World Development Report 1992*. Washington, DC: The World Bank
- Shahzad, S., Kumar, R., Zakaria, M. & Hurr, M. (2017). Carbon emission, energy consumption, trade openness and financial development in Pakistan: A revisit. *Renewable and Sustainable Energy Reviews*, 70, 185-192.
- Shen, J. (2006). A simultaneous estimation of Environmental Kuznets Curve: Evidence from China. *China Economic Review*, 17(4), 383-394.
- Singer, J.D., Bremer, S. & Stuckey, J. (1972), Capability Distribution, Uncertainty, and Major Power War, 1820-1965, in B. Russett, ed., 'Peace, War, and Number', Sage, Beverly Hills, 19-48.
- Stafford, S. L. (2000), 'The Impact of Environmental Regulations on the Location of Firms in the Hazardous Waste Management Industry', *Land Economics* 76, 569-589.
- Stern, D. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development*, 32(8), 1419-1439.
- Stern, D., Common, M. & Barbier, E. (1996). Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development. *World Development*, 24(7), 1151-1160.
- Stock, J. & Watson, M. (2012). *Introduction to Econometrics*. 3rd ed. England: Pearson Education Limited.
- Suri, V. & Chapman, D. (1998). Economic growth, trade and energy: implications for the environmental Kuznets curve. *Ecological Economics*, 25(2), 195-208.
- Tilly, R. (1990). Industrialisation as an Historical Process. *European History Online*.
- TIME.com. (1975). *Environment: Pollution's High Price*. [online] Available at: <http://content.time.com/time/magazine/article/0,9171,912986,00.html> [Accessed 9 Oct. 2017].
- Tröger, V. (2008), 'Problematic Choices: Testing for Correlated Unit Specific Effects in Panel Data', *Paper prepared for the Political Methodology Meeting in Ann Arbor 2008*.

Tullock, G. (1967). Excess benefit. *Water Resources Research*, 3(2), 643-644.

Wilson, S. & Butler, D. (2007). A Lot More to Do: The Sensitivity of Time-Series Cross-Section Analyses to Simple Alternative Specifications. *Political Analysis*, 15(02), pp.101-123.

Wooldridge, J.M. (2013), *Introductory Econometrics: A Modern Approach*. Fifth International Edition. Thompson South-Western, Mason.

World Bank (1992). *World Development Report 1992: Development and the Environment*. New York: Oxford University Press.

World Bank (2017), 'World Development Indicators.'

APPENDIX

Table 8. Countries in the panel data set⁶

Country	Time period	Income category
Albania	1998-2013	UM ⁷
Algeria	1998-2013	UM
Angola	1998-2013	UM
Argentina	1998-2013	UM
Armenia	1998-2013	LM
Australia	1998-2013	H ⁸
Austria	1998-2013	H
Bahrain	1998-2013	H
Bangladesh	1998-2013	LM ⁹
Benin	1998-2013	L ¹⁰
Bosnia And Herzegovina	1998-2013	UM
Botswana	1998-2013	UM
Brazil	1998-2013	UM
Burkina Faso	1998-2013	L
Burundi	1998-2013	L
Cambodia	1998-2013	LM
Cameroon	1998-2013	LM
Canada	1998-2013	H
Central African Republic	1998-2013	L
Chad	1998-2013	L
Chile	1998-2013	H
China	1998-2013	UM
Congo, Rep	1998-2013	LM
Croatia	1998-2013	UM
Czech republic	1998-2013	H
Dominican republic	1998-2013	UM
Ecuador	1998-2013	UM
Egypt, Arab Rep	1998-2013	LM
El Salvador	1998-2013	LM
Ethiopia	1998-2013	L

⁶ Source: World Bank

⁷ Upper Middle Income

⁸ High Income

⁹ Low Middle Income

¹⁰ Low Income

Finland	1998-2013	H
France	1998-2013	H
Georgia	1998-2013	UM
Germany	1998-2013	H
Ghana	1998-2013	LM
Haiti	1998-2013	L
Honduras	1998-2013	LM
Hungary	1998-2013	LM
India	1998-2013	LM
Iran, Islamic Rep	1998-2013	UM
Italy	1998-2013	H
Japan	1998-2013	H
Kuwait	1998-2013	H
Lao PDR	1998-2013	LM
Malawi	1998-2013	L
Mali	1998-2013	L
Mexico	1998-2013	UM
Nepal	1998-2013	L
Nigeria	1998-2013	LM
Pakistan	1998-2013	LM
Paraguay	1998-2013	UM
Peru	1998-2013	UM
Portugal	1998-2013	UM
Romania	1998-2013	UM
Russian Federation	1998-2013	UM
Rwanda	1998-2013	L
Senegal	1998-2013	L
South Africa	1998-2013	UM
Sri Lanka	1998-2013	LM
Tanzania	1998-2013	L
Thailand	1998-2013	UM
Tunisia	1998-2013	LM
Turkey	1998-2013	UM
Uganda	1998-2013	L
Ukraine	1998-2013	LM
United kingdom	1998-2013	H
United states	1998-2013	H
Uruguay	1998-2013	H
Zambia	1998-2013	LM
Zimbabwe	1998-2013	L

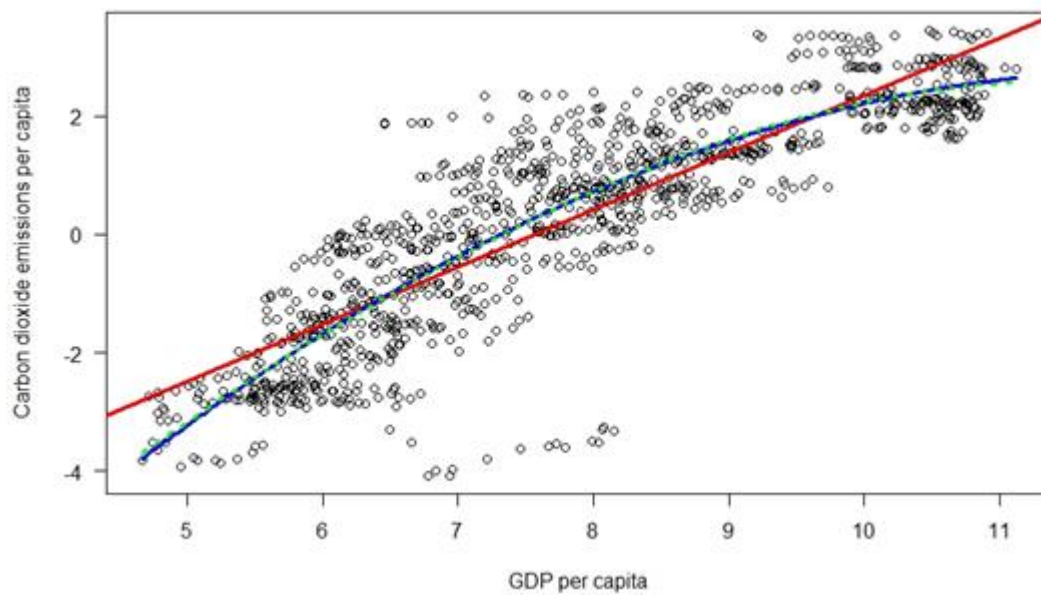


Figure 3. Scatter plot of Carbon dioxide emission per capita and GDP per capita (1998-2013)

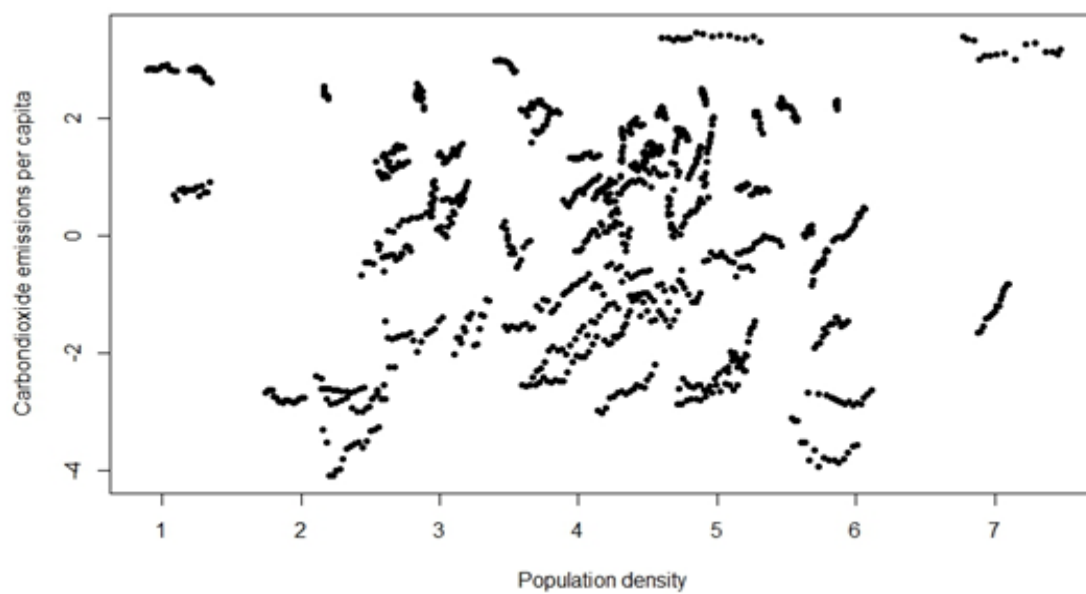


Figure 4. Scatter plot of CO₂ emissions and Population density (1998 – 2013)

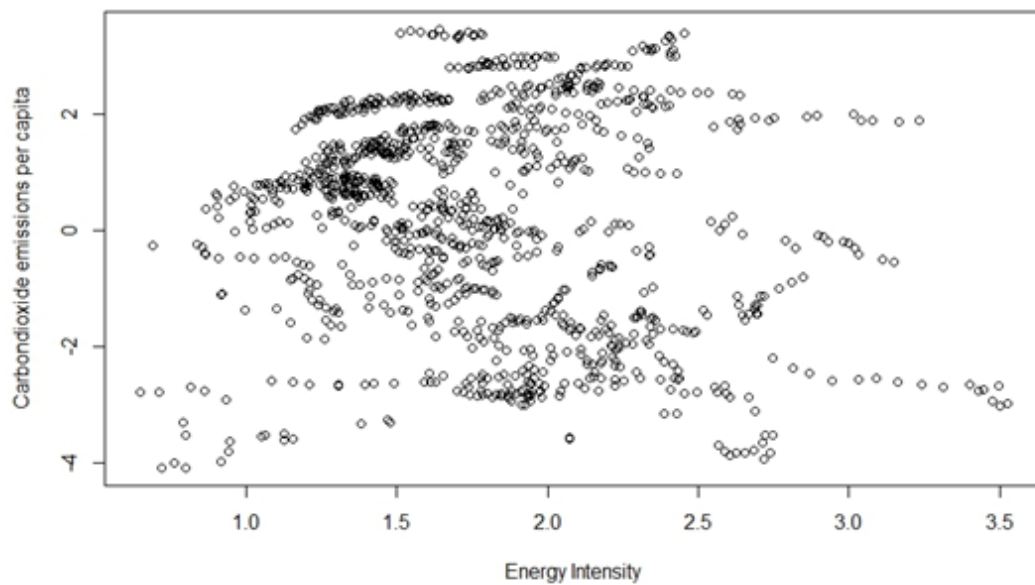


Figure 5. Scatter plot of CO₂ emission per capita and energy intensity (1998 – 2013)

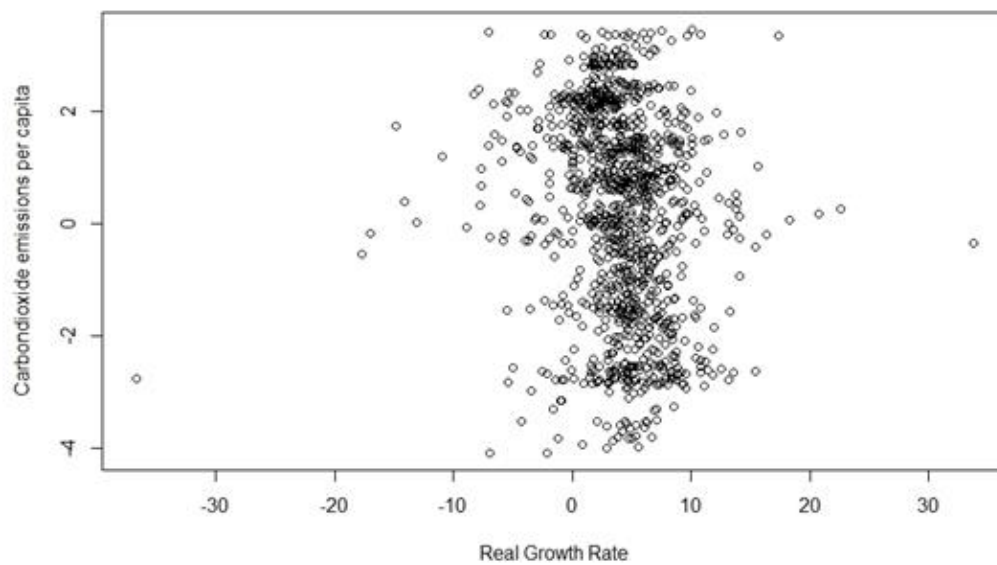


Figure 6. Scatter plot of CO₂ emission per capita and real growth rate (1998 – 2013)

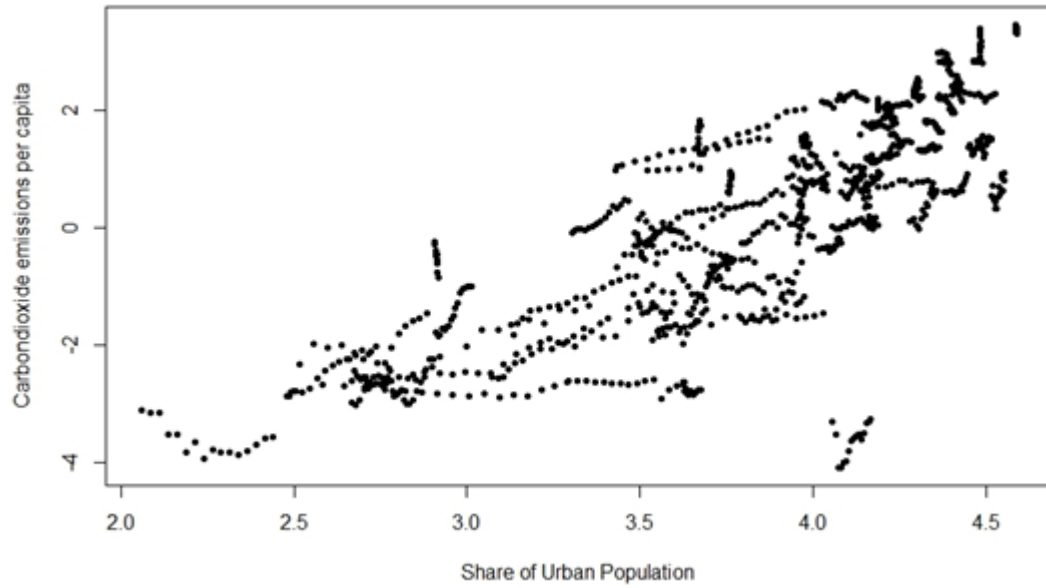


Figure 7. Scatter plot of CO₂ emission per capita and share of urban population (1998 – 2013)

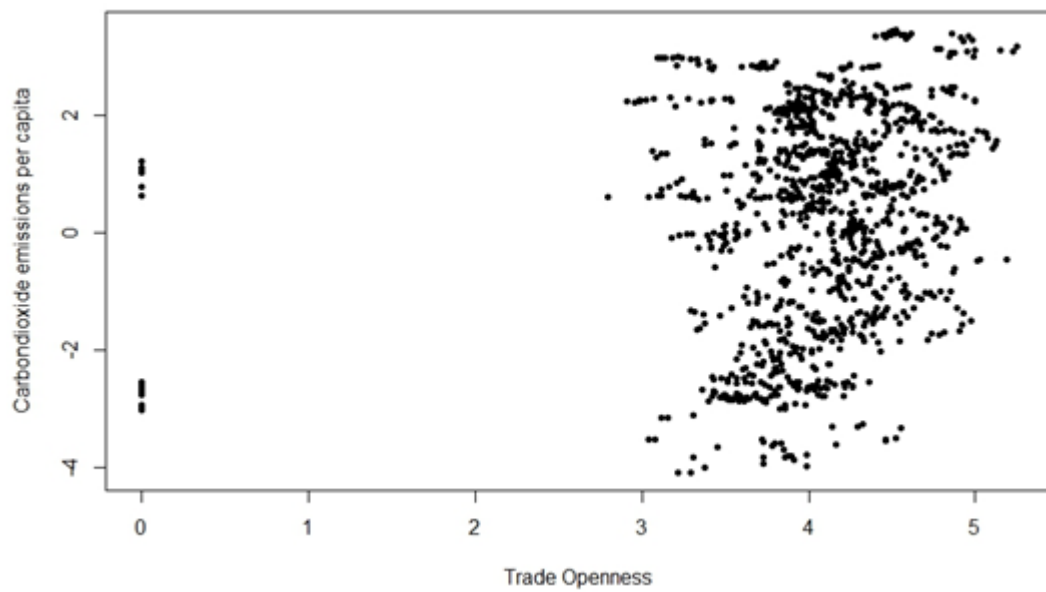


Figure 8. Scatter plot of CO₂ emission per capita and trade openness (1998 – 2013)