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The Economic Growth & Environmental Degradation Nexus in Algeria Using the Fuzzy Logic

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Dedication

This project is essentially dedicated to our beloved bounteous land Algeria. I am immensely thankful to my notable teacher, colleague and supervisor Professor Akacem Omar for his guidance; pieces of advice, patience and encouragement throughout the preparation of this work, without your help, this work would not be accomplished. I am also eternally indebted to my distinguished teacher and assistant supervisor Doctor Cheikh Saous for his remarks and instructive criticism; his substantial help and consultations have pushed me to successfully conduct this scientific research. I am especially thankful to the various scholars who instructed me to complete the current project, especially Professor Researcher Arnold F. Shapiro for providing me with invaluable resources of information. Finally, I deeply express my gratitude to my colleagues, students, friends and family members for their constant moral support, especially my dearly treasured husband, Abd El Aziz, who values knowledge as a scholar should; my beloved parents for their constant support, my brothers and sisters and my all my friends, especially Zineb and Hadjer. May Allah bless all of you.

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ملخص

تناولت هذه الدراسة تحليل العلاقة بين النمو الإقتصادي والتدهور البيئي في الجزائر كاقتصاد مصدر للنفط وذلك من خلال منهجيين للبحث، أولا بإستخدام المنهج التحليلي لدراسة الوضع الاقتصادي والبيئي في الجزائر باستعمال المؤشرات الملائمة لذلك. ثانيا بإستخدام المنهج الكمي و ذلك بتوظيف طرق التقدير التالية: طريقة المربعات الصغرى العادية ، الإنحدار الضبابي بإستخدام طريقة تاناكا (1982) و طريقة المربعات الصغرى الضبابية و ذلك من أجل إختبار نظرية منحنى كوزنتس البيئي لتلوث الهواء في الجزائر للفترة 1970-2013 . النتائج المتوصل اليها تشير إلى ان كل الطرق المستعملة في التقدير لها الإشارات الصحيحة و التي تتوافق مع فرضية منحنى كوزنتس البيئي مايقترح شكل U مقلوبة بين التلوث البيئي و النمو الإقتصادي. الإشارة السالبة لمربع الدخل الفردي الحقيقي تدل على فصل النمو الاقتصادي عن انبعاثات ثاني اكسيد الكربون للفرد عند مستويات دخل مرتفعة. بعد مقارنة نماذج التقدير المتوصل اليها، تفوقت طريقة تاناكا (1982) للتقدير على الطرق الأخرى المستعملة في تقليل خطأ التقدير. الإستنتاجات المتوصل اليها في هذه الدراسة وفي وضع الجزائر تحديدا تؤكد على أهمية وضمان أن يكون السعي الى معدل نمو إقتصادي مرتفع هو الأولوية الرئيسية للحكومة جذبا إلى جنب مع السياسات البيئية لضمان رفاهية المجتمع الجزائري.

الكلمات المفتاحية: الجزائر، منحنى كوزنتس البيئي، النمو الاقتصادي، تلوث الهواء، طرق التقدير.

Abstract

This study explores and analyzes the relationship between the economic growth and the environmental degradation in an oil exporting economy i.e. Algeria; through two methodological approaches. Firstly, the study analyzes the economic and the environmental situation in Algeria using the economic and environmental indicators. Second, it employs several estimation methods; the ordinary least square estimation method (OLS), Tanaka (1982) fuzzy regression method and the Fuzzy least square regression (FLSR) estimation method, in order to test the validity of EKC hypothesis in Algeria for air pollution during the period 1970-2013. All the estimated models have the correct signs, which are consistent with the EKC hypothesis. This suggested an inverted U-shaped relationship between economic growth and environmental degradation. The negative sign of squared term of income seems to validate the break of CO_{2pc} emissions and real GDP_{pc} at the higher levels of income. Through the conducted comparison between the used estimating methods, it has been realized that the Tanaka method is superior to other estimation methods in the sense of reducing the errors. The findings of this study recommends that, in the case of Algeria, ensuring a high economic growth rate should be the main priority of the government along with environmental policies to ensure the welfare of the Algerian society.

Keywords : Algeria, Environmental Kuznets Curve, economic growth, air pollution, estimation methods.

Résumé

Cette étude explore et analyse la relation entre la croissance économique et la dégradation de l'environnement dans une économie exportatrice de pétrole ; l'Algérie ; à travers deux approches méthodologiques. Premièrement, l'étude analyse la situation économique et environnementale en Algérie en utilisant les indicateurs économiques et environnementaux. Deuxièmement, cette étude utilise plusieurs méthodes d'estimation ; la méthode des moindres carrés ordinaires (MCO), la méthode de régression floue de Tanaka (1982) et la méthode d'estimation de régression des moindres carrés floues, afin de tester la validité de l'EKC (la Courbe Environnementale de Kuznets) hypothèse en Algérie concernant la pollution de l'air pendant la période 1970-2013. Tous les modèles estimés ont les signes corrects, qui sont cohérents avec l'hypothèse d'EKC. Cela a suggéré une relation en forme de U inversé entre la croissance économique et la dégradation environnementale. Le signe négatif du terme carré du revenu valide la rupture entre les émissions de CO_2pc et la PIBpc réelle aux niveaux des revenus les plus élevés. Apres la comparaison entre ces méthodes d'estimation utilisées, on a réalisé que la méthode Tanaka est supérieure à d'autres méthodes d'estimation dans le sens qu'elle réduit les erreurs. Les résultats de cette étude conclue que, dans le cas de l'Algérie, assurer un taux de croissance économique élevé devrait être la principale priorité du gouvernement ainsi que la politique environnementale afin d'assurer le bien-être de la société algérienne.

Mots Clés : L'Algérie, la courbe environnementale de Kuznets, croissance économique, pollution de l'aire, méthodes d'estimation.

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General Introduction

General Introduction

In the last few decades, the world has seen an increase in the environmental awareness and concerns because of the natural disasters, drought and floods in the globe, which are related to changes in the global climate. The world as a community acted to protect the environment and reduce the effects of global warming through various conventions such as: the first United Nations Conference held in Stockholm 1972, which aimed to reduce the human impact on the environment. Twenty years later, the RIO convention, which was held in Brazil in 1992, discussed the climatic change and the biological diversification. One of the most famous conventions, which is known as Kyoto Protocol in 1997, aimed to fight against the global warming. These conventions were held to reduce human damage to the globe, and to protect it in the present as well as for the next generations. Environment is the host of all human activities, including the economic activities under consideration here. The economic activity has a cyclic relationship with the environment known as the input-output processes, in which it receives the raw materials from the environment and then gives a range of types of pollution (such as waste, air and water pollution etc.,) back to the environment as an outcome of the production, consumption and utilization processes. Therefore, there is no stability and no continuity for economic development that depend on depleted resources and an environment that is constantly exposed to danger. The relationship between economic activity and the environmental degradation is explained through Kuznets Curve Theory. A vast volume of empirical studies has tested the fact that: there is an inversed-U-shaped relationship between economic activity, usually measured in terms of per capita income and the environmental quality. That is to say, at the first stage of economic growth, environmental

degradation increases as per capita income increases, but begins to decrease as rising per capita income passes beyond a turning point. This environmental pattern has been called Environmental Kuznets Curve (EKC) due to the similarity with the relationship between the level of inequality and per capita income considered by Kuznets (1955).

Algeria was also a member in various environmental international conventions such as Biodiversity, Climate Change, Kyoto Protocol, Desertification, Endangered Species, Ship Pollution, Environmental Modification, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Wetlands and others. According to the report by Environmental Performance Index (EPI), Algeria was ranked 83rd amongst 180 nations. That indicates the interest of the Algerian government in the environmental field and its attempts to improve the current environmental situation. In order to measure the economic impact on the environment, the fuzzy logic was used. The scientist Lotfi Zadeh (1973) founded the Fuzzy Logic, a discovery that made a significant advancement in different sciences. Thus, this research will use the Fuzzy Regression and the OLS Method to test the existence of the EKC in the case of Algeria for Carbon Dioxide Emissions.

1. Statement of the Problem and Significance of the Study

1.1. Statement of the Problem

This research will focus on the air pollution measured by Carbon dioxide emissions (CO_2) in Algeria. It will use both Fuzzy Regression as well as OLS (Ordinary Least Square) Estimation Methods and then, compare their results. According to the previous background, this research is based on, and aims to answer, the major following question:

❖   How far does the Economic Growth affect the Environment in Algeria?

Thus, this research aims to answer the following sub-questions:

➢   Is the Environmental Kuznets Curve still valid in Algeria after using the Fuzzy Regression?

➢   Using OLS method, is there an environmental Kuznets Curves for CO_2 in Algeria?

➢   How effective is the environmental performance in Algeria?

➢   What are the suitable solutions to increase the economic growth without worsening the environmental degradation in Algeria?

1.2. Objectives of the Study:

The research will pursue the following objectives:

➢   Shed light on the relationship between economic growth and the environment to analyze reasons causing the imbalance, and then, test the validity of the Environmental Kuznets Curve hypothesis for Algeria by employing the Fuzzy logic.

➢   Shed light on policies and possibilities that tend to improve the environmental quality while increasing and enhancing economic growth levels in Algeria.

➢   Present and analyze the environmental and economic situation in Algeria from different aspects.

1.3. Significance of Study:

The significance of this topic comes from the great importance and attention given by the whole world to the environmental pollution, global warming and its causes and also   from   the   importance of the Environmental Kuznets Curve which combines the

environmental degradation with the economic growth. Algeria is an oil exporting and developing country and it suffers from the environmental pollution and seeks sustainable development standards. Testing the validity of the Environmental Kuznets Curve in Algeria helps in providing suggestions about setting priorities to environmental policies, and in enriching the literature about the economic growth and environment in Algeria, since there is a lack of studies in this field. In addition to that, the use of fuzzy logic in estimating such indirect relationship between the economic growth and environmental degradation is very substantial.

2. Research Motivations

There are several factors that motivated the research of this PhD study. First, the dearth of research on the use of fuzzy logic in predicting the economic situation for Algeria. Second, the uncertainty as to whether fuzzy logic alone can lessens the error results and which method should be added to reduce the error even more. Third, there is a necessary need to upgrade the statistical predictions of the economic future of various countries, especially Algeria, and last, the compelling urge on the relevance of statistical methods employed, especially fuzzy logic and the methods applied on it, namely the OLS, the Tanaka method and the fuzzy regression. These motivational factors are keen to fill the knowledge gap of the subject matter, as well as enrich future further research by their contributing potential benefits.

3. Research Scope

This research will take Algeria as a case study and cover the period between 1970 and 2013. It will focus on the (1) air pollution represented by CO_2 per capita emissions as the environmental indicator and on (2) real GDP per capita as an economic indicator.

4. Research Hypotheses

This research entails the following hypotheses:

✓ The Economic growth in Algeria affects the environment negatively.

✓ The international environmental conventions may improve the economic growth in Algeria.

✓ Economic growth may improve the environmental situation in Algeria.

✓ The fuzzy logic may give more accurate results in estimating EKC.

5. Research Methodology

In order to make the analyses manageable in this research, various research methodologies will be conducted. First, the descriptive and fundamental approaches are used to describe the economic and environmental situation in Algeria based on the historical data, which were obtained from specified sources, such as: World Bank reports, Climate Analysis indicators Tool (CIAT) and data from the ministry of environment and territory management in Algeria. In addition to that, the study will employ some environmental and economic indicators in order to form the bases for analyzing the economic and environmental situation in Algeria. The quantitative approach will also be employed with the analytical and empirical study to test the existence of the EKC hypothesis in Algeria for air pollution. The latter is measured by CO_2 pc emissions during the period of 1970 to 2013, using the ordinary

least square estimation method (OLS), the Tanaka (1982) fuzzy regression method in addition to the fuzzy least square estimation method (FLSR), as an attempt to reduce the estimation error in measuring the relationship between the economic growth and the environmental degradation.

6. Literature Review:

6.1. Survey of Studies Consistent With the EKC Hypothesis:

After Grossman and Kruger (1991) study, many empirical studies appeared to test the validity of EKC model around the world. Shafik et al (1992) presented their study exploring the relationship between the economic growth and environmental quality by analyzing the pattern of different indicators. This was the background of the World Bank's report (1992) which confirmed the necessity to integrate   environmental considerations into development policy making. Many other studies, such as Yi Chia Wang et al (2011), Reka Homordi et al (2009), Lucena (2005), Michael Tuker (1995), Jean Agres et al (1999) and Fodah, M et al (2010), found a significant evidence of prevalence of EKC in individual countries as well as sets of countries, with different environmental indicators such as CO_2, SO_2, NOX, BOD etc. Panyouto (1993,1997) study supported the prevalence of EKC in developing and developed countries, when he found that, at least in the case of ambient SO_2 levels, policies and institutions can significantly reduce the environmental degradation at low income levels and speed up the improvement in higher income levels. Thereby, he concluded with a flattening EKC and reducing the environmental price of economic growth. At the same time, he suggested that developed countries could help the developing   countries   through   creative   financing   mechanisms   such   as   global environmental facilitation. Dinda (2004) indicated that, in general, less developing countries

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use their whole stock of capital for commodity production, which generates pollution for the sake of development. Differences may not only lie between the developing and developed countries in the level of pollution and income turning point level. Ying Liu (2009) found in the same country that more developed coastal regions, had a high income level of turning point than the less developed central and western regions in China.

6.2. Survey of Studies Inconsistent With the EKC Hypothesis

EKC hypothesis assumes that the economic growth in the early stages causes harm to environment but after a certain point (income turning point); the economic growth becomes a tool that fixes and reduces the environmental damage, although the economic growth continues in increasing. Some studies did not find empirical evidence to support the validation of EKC hypothesis such as Moomaw et al (1997), De Bruyn et al (1998), V. Lantz and Q Feng (2005); they instead found that CO_2 is unrelated to GDP. Both Arrow et al. (1995) and Stern et al (1996) argued that if there was an EKC type relationship, it might be partly or largely a result of the effects of trade on the distribution of polluting industries. The environmental regulations in developed countries might further encourage polluting activities to gravitate towards the developing countries as Lucas et al (1992) suggested. D. Stern et al (1996) critically examined the concept of EKC and they found that the EKC approach has much to offer in the way of informing the choices arising for policy makers. Jordi Roca et al (2001) study presented evidence that there is no correlation between higher income level and smaller emissions, except for SO_2, the evolution of which might be compatible with the EKC hypothesis. The study argued that the relationship between income level and diverse types of emissions depends on many factors. Thus, it cannot be proposed that economic growth by itself will solve the environmental problems. It

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is evident from the results of various studies that the EKC is valid in some cases and invalid for others depending on the specific circumstances prevailing in different countries. This leads us to understand that the economic development is not the only variable affecting the environmental degradation. Environment can be affected by several other factors, whether alone or mixed. These factors include, but are not limited to, trade openness, population growth, income elasticity of environmental quality demand, FDI, scale production, consumption patterns, wars...etc. According to the empirical studies done on EKC, it is important to choose suitable indicators. It is important that the income-turning point varies in the different scenarios and circumstances in terms of pollutant to pollutant and specificity of every country and the used measuring and estimating method. Although EKC has been subject to some criticism, nonetheless, it is still prevalent and provides the bases for further research by providing the flexibility for more factors, which affect the environmental degradation in a positive or negative manner. The EKC illustrates that the processes of economic growth and eliminating poverty are the "primary goal" which people look for in the early stages of economic growth.

6.3. Survey of Studies Concerning the Fuzzy Regression

The subject of this research needs further studies and more profound research to illustrate the factors, which affect the environment from the economic side. Therefore, for this reason, this research will focus on a new method called the fuzzy regression to estimate the relationship amongst the variables subject of the study.

The first fuzzy regression method is the Tanaka regression method, which has influenced various researchers. Razzaghna et al. (2007) extended the scope of using Tanaka's

model by means of trapezoidal linear fuzzy regression parameters. Jung-Hsien Chiang and Pei-Yi Hao (2007) conducted a thorough research to elaborate a fuzzy method to promote the vector regression. By using fuzzy data, Tata and Arapour (2008) organized an estimation of the coefficients of fuzzy linear regression method, whereas Bisserier et al. (2008) adapted its form to present a new model, the output of which can possess whichever type of output spread tendency. Hassanpour et al. (2009) applied a certain criterion of reducing the variance of the fuzzy membership values between the observed fuzzy numbers and the estimated ones to adjust the fuzzy linear regression. Rahim and Rasoul Saneifard (2011) used the parametric distance to estimate the models of fuzzy regression, while the model proposed by Omrani et al. (2011) is very simple and efficient to calculate the fuzzy linear regression with outliers based on the aim programming method to evaluate the upper and lower fuzzy bands.

The second approach of fuzzy regression is the fuzzy least square method, which is based on the perception of the difference between the observed and the predicted fuzzy outputs and how well they fit. Diamond's models (1987), which have been retreated later by Diamond and Korner (1997), were perfected to fit least squares for fuzzy input and output as well as for crisp input and fuzzy output, where the distance between the fuzzy numbers is set to measure the best fit for the models. Bardossy et al. (1992) defined a new class of distance on fuzzy numbers and considered the model involving fuzzy input and fuzzy parameters. Xu (1997) discussed the problem of least squares fitting of fuzzy valued data by developing a special curve regression model for fitting this type of data. Chang and Ayyub (1997) developed a method for hybrid least squares regression based on the weighted fuzzy arithmetic and least square fitting criterion. Wang and Tsaur (2000) adjusted the fuzzy least squares method to be a crisp input-fuzzy output method, while D' Urso and Gastaldi (2000)

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introduced a least squares method for the analysis of fuzzy linear regression. Hong et al. (2001) used shape-preserving operations to maintain using fuzzy input and fuzzy coefficients in conducting the least squares method for the regression model. Yang and Lin (2002) recommended that for an effective procedure of the coefficients estimation, both estimation methods should be used along with a fuzzy least squares approach. Kyung Joong Kim et al. (2005) used an absolute deviation in the fuzzy least technique that would guarantee a fuzzy linear regression model with both fuzzy input and fuzzy output. Aysen Apaydin and Furkan Baser (2010) used a new hybrid fuzzy least squares regression method to calculate the insurance claim reserves. For the sake of establishing stochastic demand in the transportation means' directing issue, while later, Fatemeh Torfi et al (2011) produced a fuzzy least squares linear regression method that fits this function.

6.4. The Literature Review of EKC Studies about Algeria

The empirical studies about existing EKC in Algeria are too limited, where; it is usually mentioned within specific divisions such as MENA countries, oil export countries, and African countries. Abdoulkarim Ismailia et al (2008) research made estimation of an environmental Kuznets curve (EKC) for oil countries. The empirical results fully support the existence of an EKC for these oil countries, while Sahbi Ferhani et al (2012) found that in the short term, there is no causal link between GDP and energy consumption and between CO_2 and emission and energy consumption. Serkan Gürlük (2009) study pointed out the differences between the Northern and Southern Mediterranean countries in the case of BOD, As for Algeria, he found significant results for GDP and modified human development index MHDI with BOD. His study results indicated the importance of human development for Algeria and developing Mediterranean countries. Christopher O. Orubu et

al (2011) study investigated the relationship between per capita income and environmental degradation in Africa. The results of the empirical investigation generally suggest the existence of an environmental Kuznets curve for suspended particulate matter. In the case of organic water pollutants, the evidence weighs more in favor of rising pollution as per capita income increases. The turning point levels of income established for the two indicators of environmental quality were however generally low, when compared to evidence from other existing studies. On the face value, this suggests that African countries may be turning the corner of the environmental Kuznets curve, much faster, and at lower levels of income, much in line with the emerging idea of a revised environmental Kuznets curve. The results also suggest that economic growth and rising incomes may matter in African countries in order to curb pollution from these pollutants, but more stringent policy measures, particularly at the industrial level, would be required to curb environmental degradation from organic water pollutants. The following studies by Paresh Kumar Narayan et al (2009) and Mohamed El Hedi Arouri et al (2012) approached more to Algeria. They examined the EKC hypothesis based on the short and long run income elasticity; that is, if the long-run income elasticity is smaller than the short run income elasticity, it is evident that a country has reduced carbon dioxide emissions as its income has increased. Algeria is one of the countries, which had this result according to the findings of these studies.

7. Summary of Literature and the Contribution of the Research

The environmental Kuznets curve (EKC) analysis is employed to explain the relationships between economic growth and environmental degradation. After Grossman and Kruger (1991) study, a huge number of studies were applied to confirm whether the EKC hypothesis exists with different environmental indicators such as CO_2, SO_2, BOD,

deforestation and other environmental indicators, with different explanatory variables in addition to GDP factors such as energy consumption, oil exports, trade openness, population etc. Relatively a large number of studies support the existence of EKC and its hypothesis. On the other hand, some studies did not find empirical evidence in favor to support the validation of EKC hypothesis such as Jordi Roca et al (2000). They argued that the relationship between income level and diverse types of emissions depends on many factors. The empirical studies about Algeria are quite limited and, in addition to the lack of the research on EKC about Algeria, we usually find this country among specific divisions such as MENA countries, oil exporting countries, African countries and Mediterranean countries. That did not give in details the fits and responsible variables which determined the environmental degradation in a developing and oil exporting country like Algeria, in the case of the environmental performance and the legislation intervention to protect the environment there. Because of these limitations, this study comes to help explain the impact of the Algerian economic growth on environment as an individual country. Lindmark (2002) argues, "Historical studies of individual countries offer an advantage over cross section approaches in bringing the analyses closer to the dynamic that causes the EKC pattern". This study will provide analyses through two stages: firstly, through the economic and environmental analyses using indicators such as macroeconomic indicators to analyze the economic situation in Algeria, and for the environmental situation analyses by using the environmental performance index (EPI), environment sustainability index (ESI) and other environmental national reports. Secondly, by testing the validity of EKC hypothesis in the case of Algeria through econometric perspective through applying the fuzzy regression estimation method.

8. Study Obstacles

The current research has so far been challenging at different levels, including finding the primary sources, conducting the literature review, undertaking the practical research, and even citing the theoretical framework, especially in the case of a research about Algeria. The researcher has ventured to enlighten this area of research in spite of that challenge, which was successfully handled, once the study was conducted in English, which enabled the study to widen the scope of research and include different methods of fuzzification to reduce the resulted errors in estimating the EKC model for air pollution in Algeria.

9. Sequence of Chapters

In order to make the research manageable, the study is divided into five chapters, which are as follows:

o   The first chapter is divided into three main sections. The first section presents and defines the natural environment and its most essential components. The second section will address the environmental pollution, in which human beings contribute greatly, by introducing its definitions, its causes, types and the manner of its formation. Finally, the third section will cover the economic tools that are employed to control and reduce the environmental pollution by displaying the international conventions and protocols in the field of environmental protection.

o   The second chapter covers the theoretical analyses of the relationship between economic growth and environmental pollution. Firstly, it will present the concept of the economic growth and the theories that explain it. Then, it shifts to discuss the environment in traditional and modern economic thought. Finally, The theoretical analyses of the

relationship between economic growth and environment have been recognized under the light of the Environmental Kuznets Curve Theory.

o   The third chapter tackles the economic and environmental situation in Algeria. This chapter has been divided into three parts. The first section investigates the economic growth experiences that Algeria has known. The second section introduces the environmental situation in Algeria. The third part discusses the efforts that Algeria has undertaken in the field of environmental protection and the international environmental conventions that Algeria has approved, as well as the local environmental protection laws that Algeria has issued.

o   The forth chapter, introduces the concepts of classical sets and fuzzy sets and their main operations and properties. Then, the traditional regression will be demonstrated by illustrating the Ordinary Least Square Method. The fuzzy regression methods will be elaborated through their types: the linear programming estimation method of Tanaka and fuzzy least square regression method (FLSR).

o   The fifth chapter contains the application environmental Kuznets Curve hypothesis for air pollution in Algeria though conducting several estimation methods. Firstly, the EKC for air pollution in Algeria will be estimated using the Ordinary Least Square estimation method, then, it will be estimated by employing the fuzzy linear regression model of Tanaka, and finally, by using the Fuzzy least Square Regression method. These estimated models will be compared according to the quality estimation. In the end. The last section contains the economic discussion and interpretations of the obtained results in the light of the environmental Kuznets curve hypothesis.

Chapter One

Chapter Introduction

Nature is considered as a refuge for all sorts of creatures including humans. Since the UN Conference about Human and Environment in 1972, the concept of environment was introduced and thus people started to care for it. This research starts by this chapter, which is divided into three important sections. The first section will discuss the natural environment and its most important components, and then the second section will tackle the environmental pollution, in which humans contribute greatly, through its definition, its causes and the manner of its formation. The third section will discuss the economic tools that are used to control pollution and reduce it, in addition to the international conferences held in the field of environmental protection.

1.1.   The Environment and Its Concepts

In view of the fact that environment is a major focus of this research, it would be useful to demonstrate clearly the term "Environment", its contents and important terms related to it in order to set up the discussion in an appropriate context.

1.1.1.   The Definition of Environment

The word Environment is a French word which has been borrowed into English. It was derived from the French word "Environ" which means "surrounding". Generally this word has different meanings, which can be defined as follows:

Definition 01: Environment literarily means 'surrounding,' and everything that affects an organism during its lifetime is collectively known as its environment. In other words, environment consists of water, air, land and their interrelationships among themselves as well as with the human being, other living organisms and property. It includes all the physical and biological surroundings and their interactions. It also encompasses the aggregate of social and cultural conditions that influence the individual's life or community[1].

Definition 02: "Environment is a word which describes all the external forces, influences and conditions which affect the life, nature, behavior and growth, development & maturation of living organism"[2].

In addition to the above definitions, the legal definition of the environment is considered as follows:

Definition 03: the Algerian law did not give a clear definition to the environment. Unfortunately, *Environment* remains a poorly defined term, where, the law number 03/10,

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[1] Anjum Ahmed, Tabassum Chowdhury, "Study of Awareness OF Environment," *Excellence International Journal Of Education And Research* a *Multi-Subject Journal*, VOLUME 1 ISSUE 4, December (2013): 389.

[2] Y.K. Singh, *Environmental Science* (New Delhi: New Age International, 2006), 02.

under decree 02 stated the objectives of environmental protection, while the subject 03 from the same law included components of the environment as follows:

✓ Environment in which man lives include natural and physical resources such as air, water, land, living and non-living organisms

✓ The qualities and characteristics of locations, places, areas and heritage-values of regions.

Based on the above definitions the following definition of *Environment* is concluded as follows:

The term *Environment* is defined as the sum total of conditions that surrounds something or somebody at a given point of time and space. It is comprised of interacting systems of biological, physical and cultural elements, which are interlinked both individually and collectively. Those surroundings or conditions contribute to surviving or maintaining the life of organism. It influences the growth and development of living organisms.

1.1.2. The Main Components of Environment

Environment consists of four basic components for the surviving life cycle on the Earth; these elements of environment are as follows:

1.1.2.1.   The Lithosphere (Land)

The lithosphere is the outer part of the Earth. It is about 100 kilometers (62 miles) thick of which the plates that contain the ocean basins and the continents are composed. The term lithosphere has often been used to refer to the entire layer of the earth, from the earth crust to the innermost crust. The lithosphere is not composed of uniform

thickness. It is thicker in the core of the continents where it ranges between 80-100km, and the thinner under the ocean, where it lies at approximately 40 km[1].

The lithosphere is the home of man and thousands of living creatures of both plants and animals; moreover, it gives shelter to several kinds of minerals and rock types. The lithosphere supports the pillar for agricultural practices, which facilitate sustaining life. Most of the mineral resources required by human in his quest for industrial development are obtained from the lithosphere. The following table shows the compositions of the outer layer of the Earth.

Table (1.1): The Chemical Elements of Earth's Crust (Outer Layer)

Chemical Element	Percent (by weigh)	Percent (by volume)
Oxygen (O)	47	93.5
Silicon (Si)	28	0.9
Aluminum (Al)	8	0.5
Iron (Fe)	5	0.4
Calcium (Ca)	3.5	1.0
Magnesium	2.1	0.3
(Mg)	2.8	1.3
Sodium (Na)	2.6	1.8
Potassium (K)	0.2	—
Carbone (C)	0.2	—
Hydrogen (H)	0.5	—
Titanium (Ti)	0.1	—
Phosphorous (P)	0.1	—
Sulphur (S)		

Source: "Composition of the Crust," Sandatlas, accessed April 12, 2014, http://www.sandatlas.org/composition-of-the-earths-crust/

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[1] Olomo, R.O, Elakhame L.A, Azi S.O and Ighodalo O.R.A. *Elements of Environmental Studies in History and Philosophy of Science* (Ekpoma- Nigeria: Edo State University Publishing House, 1999), 37.

The major processes in the lithosphere are continental drift and weathering. These processes occur at a slow pace. Their impacts are not easily noticeable, especially in short terms. Weathering, which is the physical, chemical and biological break down of rocks and minerals, facilitates the process of soil formation[1], while the continental drift refers to the movement, formation, or re-formation of continents described by the theory of plate tectonics and theory of continental drift.

1.1.2.2.   The Hydrosphere (Water)

The hydrosphere is the liquid component of Earth. It generally refers to water of the earth in its three states –liquid, solid and gas. It includes the oceans, seas, lakes, ponds, rivers and streams. The hydrosphere covers about 70% of the Earth surface and is the home for many animals and plants. About 97% of water of the Earth is in the salty oceans, while another 2% is found in ice caps and glaciers. Collectively, the salty water in oceans and ice constitute more than 99% of the total water[2]. Unfortunately, both sources are generally inappropriate for human use due to the high salinity levels and distance. Thus, the amount of water which all the people, plants, and animals on earth struggle to use is much less than one percent of the total. Fresh potable water in liquid condition is found on and under the Earth surface. Most of the proportion of fresh water is held in deep storage, while water held in the soil within the reach of plant roots is just about 0.011% of the hydrosphere. Water held in streams, lakes, marshes and swamps is called surface water. Figure (1.1) shows the various sources of water in the hydrosphere.

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[1]   Odafivwotu Ohwo, Godwin Ekop, " ENVIRONMENTAL PERCEPTION", Course, National Open University of Nigeria, School of Science and Technology, Nigeria, 07, accessed January 2nd   ,2014, http://www.nou.edu.ng/uploads/NOUN_OCL/pdf/edited_pdf3/ESM%20403%20ENVT%20PERCEPTION%20UNEDITED.pdf

[2]   Ibid., 08.
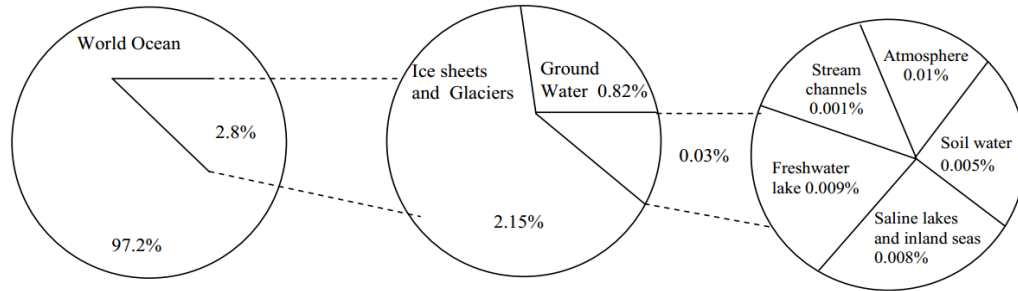
Figure (1.1): Various Sources of Water in the Hydrosphere

Source: Olomo, R.O. *Elements of Environmental Studies in History and Philosophy of Science, 17.*

The oceans and seas are the ultimate container for terrestrial water flowing from rivers. Because of their size and their mixing, the oceans and seas liquefy many human produced wastes to relatively less harmful or harmless levels. They play a major role in regulating the climate of the earth by helping to distribute solar heat through its currents water and evaporation as part of the hydrologic cycle. Moreover, they participate in other major bio-geochemical cycles. In addition, the oceans and seas serve as a gigantic reservoir of carbon dioxide, which improves regulating the temperature of the atmosphere, and they provide habitats for about 250,000 species of marine plants and animals, which provide food for many organisms and creatures, including human beings. Furthermore they serve as a source of the raw materials such as iron, sand, gravel, phosphates, magnesium, oil, natural gas and many other valuable resources[1].

The total average annual water (runoff) from earth's rivers is approximately 47,000 km^3. In recent years, the estimates of the total mass (or weight) of water used on earth per year has been approximately 100 times of the world's total production of minerals, including

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[1] Miller, G.T, *Living in the Environment Principles, Connections and Solutions, 9th eddition* (California: Wadswroth Publishing Company, 1996), 32.

petroleum, coal, metal ores, and nonmetals. The various locations of water available on the earth surface are linked together through the hydrologic cycle-movement and endless recycling of water between the land surface, atmosphere and underground.

1.1.2.3.The Atmosphere (Air)

The atmosphere is the envelope of gases surrounding the earth or other planets. It envelopes objects in space, like stars and planets, or the air around any location. The atmosphere provides the most fundamental needs for oxygen, pressure and proper temperature. Without the atmosphere, one side of our planet would be frozen, while the other part would be over heated by solar radiation. Fortunately, the atmosphere spreads just the right amount of sunlight and contains just the right mixture of oxygen, nitrogen and carbon dioxide to sustain life[1].

The atmosphere is divided into several layers, known as spherical layers-much like the successive layers of skin on an onion. About 95 percent of the air is found in the innermost layer which is known as the *Troposphere*, extending only about 17 km above the earth's surface. About 99 percent of the volume of clean dry air in the troposphere consists of two gases: nitrogen (78%) and oxygen (21%). The latter is necessary for cellular respiration for animals and plants as part of the carbon cycle. The remaining volume of the air in the troposphere has slightly less than 1 percent of Argon and about 0.035 percent of carbon dioxide. Air in the troposphere also holds water vapor which varies from 0.01 percent by volume at the frigid zones to 5 percent in the humid tropical ones. Large masses of air in the troposphere are heated by the sun rises and is replaced by cooler air. The

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[1] Olomo, R.O. *Elements of Environmental Studies in History and Philosophy of Science, 17*.

physical processes that cause these movements to happen throughout the troposphere are considered as key factors in determining the earth's weather and climate[1].

The second layer of the atmosphere is known as the *Stratosphere*. Extending from 17 to 48 km above the earth's surface, it contains a small amount of gaseous ozone (O^3) that filters out approximately 99 percent of the incoming harmful ultraviolent (UV) radiation. By preventing large amounts of this harmful radiation from reaching the earth's surface and by filtering out high-energy UV radiation, stratospheric ozone also keeps much of the oxygen (O^2) in the troposphere from being converted to the ozone.

The trace amounts of ozone that form in the troposphere as a component of urban smog damage the respiratory systems of people and other animals, plants, and even damages materials such as rubber. Thus, our health depends on having enough *good* ozone in the troposphere. Unfortunately, the human activities are decreasing ozone in the stratosphere and increasing it in the troposphere.

The *Mesosphere* is the next layer of the stratosphere. It extends from 50 to 80 kilometers. The mesosphere is recognized to be the coldest part of the atmosphere because of its steady declining temperature. Despite its altitude, the composition of the air at this point is similar to what is obtained at sea level.

The next layer of the mesosphere is the *Thermosphere*. It extends from 80 to 300 km and is characterized by high temperatures. The temperature ranges from 5000 C to 20000 C and depends on the level of activity on the surface of sun. The composition of the atmosphere of this layer is quite different from other layers. Even within the thermosphere, the

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[1] Miller, G.T, *Living in the Environment Principles, Connections and Solutions, 35.*

composition is not uniform; hence, the distance between 100 and 300 km is called the *Heterosphere*, and the atmosphere below is called as the *Homosphere*.

1.1.2.4. The Biosphere (Life Bearing Layer)

The Biosphere is the global ecological system that integrates all living beings and their relationships. More simply the biosphere can be defined as the layer of the atmosphere that supports or bears life besides the hydrosphere and the lithosphere. This layer extends from the depths of the oceans to the summits of mountains. However, most life exists within a few meters of the surface. Therefore, the biosphere can be said to comprise of all the living organisms on the earth and their interacting environment. Figure 01-02 shows a diagrammatic representation[1] of the inter-relationship among the four components of the environment.
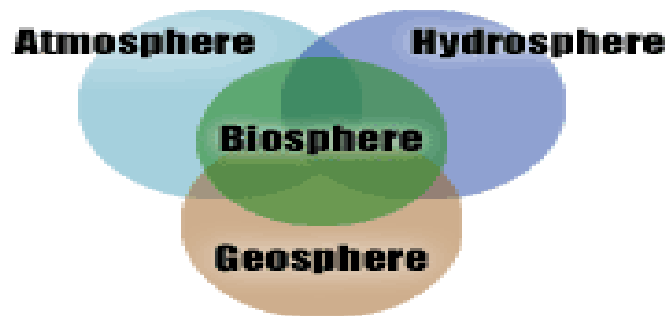
Figure (1.2): Diagrammatic Representation of the Inter-relationship among the Components of the environment

Source: "Lithosphere Hydrosphere Atmosphere Biosphere," NANOZINE, accessed March 3, 2014, http://www.nanozine.org/lithosphere-hydrosphere-atmosphere-biosphere.html

Inside the biosphere, there is a complex system of interactions and interrelationships that exists between different species that constitute the biosphere.

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[1] Olomo, R.O. *Elements of Environmental Studies in History and Philosophy of Science, 45*.

1.1.3. Commoner Law and Ecological Concepts and Their Functions

It is necessary here to clarify what the term Ecology means and what its functions are, in addition to an important ecological law, which is known as ecological Commoner Laws.

1.1.3.1.Ecological Concepts

Definition of Ecology: The word ecology is derived from the Greek word *Oikos* that means habitation, house or living relations, and *Logos*, which means discourse or study that implies a study of the habitations of organisms. Ecology was first described as a separate field of knowledge in 1866 by the German Zoologist Ernst Haeckel, who invented the word Ecology for "the relation of the animal to its organic as well as its inorganic environment", particularly its friendly or hostile relations to those animals or plants with which it comes in contact. Other investigators have variously defined ecology as the "scientific natural history", "the study of biotic communities", or "the science of community population". Probably the most comprehensive and simple definition is "a study of animals and plants in their relations to each other and to their environment.

Synecology deals with the study of communities, and *Autecology* is the study of species. There is some confusion in these terms, since Europeans commonly use *ecology* in man over sense - meaning the environmental relations of organisms or of communities. The broader study of communities, including interrelations among species and community structure and function as well as environmental relations (Synecology), is generally termed by Europeans as bio ecology or "bio-sociology"[1].

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[1] Biodiversity Conservation, "Ecological Concepts, Principles and Applications to Conservation", Canada Cataloguing in Publication Data, 2008, 08, accessed April 20th , 2014 http://www.biodiversitybc.org/assets/pressReleases/BBCPrinciplesWEB.pdf

➢ **Definition of Eco-System**

The term eco-system implies to a local community of organisms interacting with their local non-living environment. In other words, the interdependence of living and non-living aspects i.e. plants, animals, man, forest, soil…etc. create an eco-system. It is defined as a unit, which includes all the organisms (biological component) in a given area interacting with the environment (physical component) so that the flow of energy leads to a clearly defined tropic (nutrient supply) structure, biotic diversity and material cycles.

It means every eco-system has a flow of energy and cycling of nutrients, which bind the biological and physical components together. Every eco-system has a certain capacity to sustain its components without deterioration, which is called its carrying capacity. An ecosystem does not remain constant, and its changes occur continuously in various forms. It is significant that even a small change in one part of an ecosystem is felt throughout the entire ecosystem. This fact establishes the importance of interrelations in an eco-system. However, this system tries to maintain the stability of an eco-system and is resistant to change. The major eco-systems of the world are seas, fresh waters swamplands, streams, rivers, lakes, ponds, deserts, grasslands and forest. Broadly speaking, the ecosystem can be divided into two major categories[1]:

1) Aquatic or water eco-system such as seas, rivers, ponds…etc.

2) Terrestrial or land eco-system such as deserts, forests…etc.

The eco-system constitutes a very important unit of environment. It consist of three main components namely producers, consumers, decomposers and reducers. Producers basically include plants which act as self-nourishing organisms. These plants contain

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[1] Joseph Alcamo, Elena M. Bennett, *Ecosystems and human well-being: a framework for assessment*, *Millennium Ecosystem Assessment Program*, (California: University of California, 2003), 240.

chlorophyll and with its help, they obtain solar energy and manufacture it into food, and they act as a starting point in a the food chain, thus all living organisms depend on the existence of producers for their requirements of food as a primary source of energy.

1.1.3.2.Functions of the Eco-System

Every eco-system has specific functions, the most important of which are classified as follows:

1) The ecosystem performs the most important function of fulfilling the requirements of different aspects of the biotic components.

2) It is through an ecosystem that the interaction as well as interdependence between the biological components and the physical components in the environment takes place. This interdependence exists between abiotic and biotic components, for instance plants depend on solar energy and soil. The interdependence also exists between different aspects within the biotic components, for instance the carnivores depend on herbivores.

3) Ecosystems lead to transfer food energy and nutrients from one source of energy to another source.

4) The different forms of eco-systems are beneficial, because they lead to positive effects on the environment, which in turn helps the living organisms.

5) Eco-systems have helped human beings by providing materials as well as services necessary for survival as well as development[1].

There are two dominant theories of the control of ecosystems based on the environmental balance. The first one called the *bottom-up control* states that it is the nutrient supply to the primary producers that ultimately controls how ecosystems function. If the

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[1] Joseph Alcamo, Elena M. Bennett, *Ecosystems and human well-being: a framework for assessment*, *Millennium Ecosystem Assessment Program, 247.*

nutrient supply is increased, the resulting increase in production of autotrophs is propagated through the food web and all of the other trophic levels will respond to the increased availability of food (energy and materials will cycle faster).

The second theory called the *top-down control* states that predation and grazing by higher trophic levels on lower trophic levels ultimately control ecosystem function. For example, if you have an increase in predators, that increase will result in fewer grazers, and that decrease in grazers will result in turn in more primary producers because fewer of them are being eaten by the grazers. Thus, the control of population numbers and overall productivity *cascades* from the top levels of the food chain down to the bottom trophic levels.

1.1.3.3.Ecological Commoner Laws

In the early 1970s, the ecologist Barry Commoner wrote *The Closing Circle*, in which he studied the rapid growth of industry and technology and their persistent effect on all forms of life. He indicated that we could reduce the negative effects by sensitizing, informing and educating ourselves about our connection to the natural world. Commoner summarized the basics and principles of ecology into what he termed *Laws of Ecology*. Other scholars have also used this idea to develop simple statements that help us remember and understand our connections to nature. The five laws of ecology are as follows[1]:

Law 1. Everything Is Connected to Everything Else

The essential message behind this law is that all things are connected to each other, sometimes in very obvious and easy ways, and sometimes in complex and indirect ways. To illustrate this law, the concept of *food chains* that was pioneered by Al Jahiz in the 8th century,

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[1] Reef F. Noss, Allen Y. Rodger Schlickeisen, *Saving Nature's Legacy: Protecting and Restoring Biodiversity*, (Washington D.C: Island Press, 1994), 267-268.

and the concept of *food webs* that was developed from it later by Charles Elton, will be discussed in the following part.

> ➢ **Food Chains and Food Webs**

The essence of life begins with light from the sun. It continues with the transfer of this energy from the sun to plants and to animals. This series of connected organisms is called a *food chain*, a term that was pioneered by the zoologist and biologist Al Jahiz. Food chains are simple models that illustrate food relationships between different organisms. All food chains have a common beginning, which refers to the sun's solar energy. Producers receive this energy and convert it into food for primary consumers (herbivores) and secondary consumers (carnivores). Each species, including human beings, is considered as a link in several chains. The rabbit eats many different plants, and the owl consumes other animals besides rabbits. Both animals are interrelated to hundreds of chains. These interlocking chains comprise a *food web*. The exchange of elements between organisms and their physical environments is called the biogeochemical cycle or nutrient cycle. This web of chains may seem confusing and disorderly, but as a matter of fact, the web is highly structured and stable. When a strand of the web is altered or cut, many other strands are affected and harmed and must be adjusted[1].

Law 02. Everything Has to Go Somewhere or there is No Such Place as A Way

In any ecosystem, there is a limit to the amount of minerals, nutrients, air, water and soil that are available within the system and the rate at which they can be imported from outside the system. These substances must be recycled to support the living members of the system. Any disturbance in these cycles can jeopardize the entire system.

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[1] Ibid.

When life-supporting materials cycle through ecosystems, they can act as toxins, like pesticides, herbicides, heavy metals and naturally occurring radioactive substances. Unfortunately, Commoner's Laws apply to unnatural, as well as natural substances. Everything humans make and dispose of must go somewhere. Often these poisons penetrate into the living tissues of plants and animals, including humans[1].

Law 03. Everything Is Always Changing

➢ **Ecological Succession**

The species of plants and animals that are found in a community do not remain the same forever. Rather, over long periods of time, they change, mainly due to the activities of the plants and animals themselves. This change is called *Ecological Succession*, which is witnessed all around us, as when abandoned farmlands change to forests. This same process can be seen in an abandoned house lot in a city.

When the climax community or a mature forest is reached, the new generation replaces the old generation. As changes in the landscape occur, whether natural or unnatural, creatures' lives change as well[2].

➢ **Adaptation and Natural Selection**

The dominant species often live in the best habitat while the weaker species are forced into less ideal habitats. Competition, whether between species or between individuals of the same species, results in the process of natural selection. The subsequent changes in the species are called adaptations. An adaptation can be:

  1) A physical or structural change, such as camouflage coloring,

  2) A behavioral change, such as migration,

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[1] Ibid., 269.
[2] Ibid.

3) A metabolic change, such as hibernation or estivation.

Just as individuals experience success with adaptation, they pass on the trait to their offspring. Eventually, adaptations become the built-in tools that increase the chances of the organisms' survival.

Law 04. There Is No Such Thing as a Free Lunch

In the Earth's early history, only catastrophic changes, such as volcanic eruptions, earthquakes, floods and meteor showers, disrupted the balance between plants, animals, decomposers, water or air. Then, approximately two million years ago, human beings were to enter the interconnected web of life. According to Aldo Leopold, "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we might begin to use it with love and respect." Actually, some people on some pretexts believe that this earth must be at their service but they are a part of it and they must take care of it[1].

In modern times, substantial changes in medical care, world-wide communication, and modes of travel, computer capabilities and other sophisticated technologies have been observed. Many of these have made our lives easier and better, but at what cost? These gains and advances have not come free, neither in terms of money nor environmental stress. To understand some of these costs, let us consider only one part of lunch purchased at a local fast-food restaurant, which is toasted sesame seed bun[2].

To begin, the ground must be prepared (often adding chemical and organic fertilizers), farmers buy the wheat seed, plant it and care for the crop until it is ready for harvest. To protect the crop from insects, weeds and disease, a farmer often sprays chemical

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[1] Ibid., 270.
[2] Ibid.

pesticides and herbicides. The harvested wheat is shipped to the mill where it is refined and bleached (The process removes the wheat germ and bran, thus the nutritional value of the flour is decreased). The flour is sold to the bun factory where chemicals are added to the flour to enhance flavor and hinder spoilage. The buns are baked and then shipped to the restaurant. What are the costs of this process to ourselves, others and the environment? Here are a few:

- Insects and weeds become resistant to chemicals when they are constantly exposed to them.

- The farmer might attempt to control insects by using more chemicals.

- The overuse of these extra chemicals might result in being washed into streams.

- Extra chemicals cost more money and larger doses of chemicals harm birds, mammals and other insects that the farmer does not necessarily wish to kill.

- Overuse of fertilizers can also result in the excess running off into streams, lakes and ponds, causing subsequent algae blooms and resulting in depleted oxygen levels for aquatic life.

- Farmers risk exposure to chemicals that may cause temporary illness or, in extreme cases, permanent disabilities.

- The cost of the energy is enormous. Consider the following cost in this process:

1. The cost of running farm machinery for sowing, planting and harvesting.

2. Transportation costs for moving raw, processed and finished products around the country.

3. Energy and costs to run ovens, stoves and toasters to prepare the buns.

It is clear from this example that everything we do on the Earth has costs, some less obvious than others. You can trace all modern conveniences and products back to their environmental origin and predict their future costs. Some of our activities, such as trash

disposal and groundwater contamination, have disrupted the natural ability of ecological systems to maintain themselves[1].

Law 05. Everything Has Limits

For many years, it was believed that there was no end to what we could take from the Earth. There were always more fish in the sea, more trees to be cut, more mineral to be mined, more earth to be tilled and more places to dump our trash. Currently, we realize that this is not true. Some resources, called renewable resources, can be replaced if conditions are suitable, if there is enough time and energy and nutrients are available. Renewable resources include trees, wildlife and agricultural crops. They will continue to be available only if they are replaced faster than we use them. Many of the products we use on a daily basis, including energy, are made from non-renewable resources, especially oil, coal and minerals. Although there are very large amounts of these resources available worldwide, there is a limit to how much there is, and we will eventually use it all. Conservation and recycling can make these resources last for a much longer time.

Other connotations are assumed to this law. One of those is the ability of the Earth to absorb waste products, particularly toxic wastes. Removal of waste in ocean in some cases continues to be a common practice. It was believed that because the oceans were so vast that they would be able to liquefy toxic materials to such an extent that we would never be able to detect them, and they would never cause any harm. At present, it has been realized that this is not the case, and we have begun to restrict ocean dumping[2]. Similarly on land, some ecosystems, such as wetlands and certain types of soil, are known to be able to absorb the

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[1] Michael Egan, *Barry Commoner and the science of survival*, (England: the MTP press, Cambridge, Massachusetts, 2007), 122.
[2] Michael Egan, *Barry Commoner and the science of survival*, 124.

large amounts of toxic materials and neutralize or absorb them. Over again, we have learned that there are limits to what these systems can handle. The land and the soil can be renewed through the processes of erosion and decay. But if erosion occurs before new soils can be created, that resource will also be depleted and consequently soil would be washed to the sea, and it would be very difficult to recover it.

The resources available to us, both renewable and non-renewable, have some limits. With non-renewable resources, once they are consumed, they can never be replaced and they are non-biodegradable. Renewable resources will be available only if we conserve and replace them faster than we use them. We must learn to balance our use of natural resources with their availability and renewability.

1.2. The Environmental Pollution

It was believed that the Earth has the ability to absorb all waste products, particularly toxic wastes, but, at present, it has been realized that this is not the case. In this context, we intend to see the concepts and types of environmental pollution beside the used economic control tools of it.

1.2.1. The Definition, Causes and the Formation of Pollution

Nowadays, most countries are experiencing pollution from moderate to severe levels, which places growing strains on the quality of air, soil and water. Despite clean-ups in some sectors and countries, a massive expansion in the use of chemicals throughout the world, exposure to heavy metals, pesticides, small particulates and other substances all pose an increasing threat to human environment and health.

1.2.1.1.The Definition of Pollution

Pollution was taken from the Latin word "Pollutionem" that means defilement from pollution to soil[1].

Definition 01: Pollution is defined as the process that introduces pollutants and commitments resulted from human activities to the natural environment, and that causes imbalance, instability, disorder and harm to the ecosystem[2].

Pollutant is defined as a substance that pollutes the water[3], air or land. This word is used to describe unnatural things introduced to the environmental nature.

Definition 02: The Algerian law number 03/11 subject 04 paragraph 09 related to environmental protection in the context of sustainable development defined pollution as "all direct and indirect changes in environment that cause harm to public health, safety of human beings, animals, air, water, land, collective and individual property"[4].

From the above definitions, we can conclude and define pollution as the introduction of pollutants to the natural environment, and that these pollutants are resulted from human activities that led to a disequilibrium in the environmental ecosystem.

1.2.1.2.The Causes of Pollution

There are many causes that create the environmental degradation and worsen it rapidly. These reasons can be summarized in the following reasons related to economic

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[1] V. V. K. Subburaj, *Sura's Yearly Book*, (India, 2007) 513.

[2] William Cunningham, Mary Cunningham, *Principles of Environmental Science* (Canada: McGraw-Hill Companies, Incorporated, 2010), 245.

[3] Oxford Advanced Learner's Dictionary, 8th ed. (United Kingdom: Oxford university Press, 2010), 1173.

[4] Official Journal, *the Protection of the Environment as a Part of Sustainable Development Act No. 03-10,* vol. 43 (Algeria: 19 July 2003), 10.

growth, population growth and technological development and they affect the environment directly:

P: Refers to Population growth

A: Consumption average per capita

T: Technology

The impact on the environment is determined by the previous three factors that work in a coherent way according to "Ehrlich et Holdren" known as Environmental Impact Equation following equation:

$$I = P \; X \; A \; X \; T \qquad (1.1)$$

IPAT equation describes the multiplicative contribution of population (P), affluence (A) and technology (T) to environmental impact (I). Environmental impact may be expressed in terms of resource depletion or waste accumulation. Population refers to the size of the human population. Affluence refers to the level of consumption by that population. Technology on the other hand, refers to the processes used to obtain resources and transform them into useful goods and wastes. The formula was originally used to emphasize the contribution of a growing global population on the environment, at a time when world population was roughly half of what it is now. It continues to be used with reference to population policy[1].

It should be noted that the factor of population growth is one of the most important factors of environmental degradation in developing nations, while in the developed countries the consumption behaviors and the technological development make the effect.

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[1] Phillipe Bontems, Gilles Botillon, *Economie de l'environnement* (Paris, 1998), P8.

1.2.1.3.The Formation of Pollution

The majority of pollution affecting human societies originates from human activities and is consequently susceptible to human control. Human activities create pollution sometimes mentioned as *Anthropogenic Pollution*, which is a category of pollution that has existed for centuries. After the industrial revolution, people living in cities were and still are exposed to huge quantities of noxious gases in the air and dangerous levels of harmful materials in their water supplies. However, most people of the time probably accepted such risks as part of being city dwellers[1]. Modern concerns about pollution appear largely as the result of two factors. First, population growth in many urban areas meant that more people and more industries were releasing a higher concentration of pollutants to the environment than ever. Second, modern science has developed a number of new materials and new procedures that resulted in the release of many new and often dangerous chemicals to the environment. As people became more and more conscious of pollution problems, they began calling for government efforts to control the release of pollutants and to clean up dirty environment. The following figure (1.3) shows the pollution formation and the way to control it in cities[2].

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[1] Christopher Wood, *Town Planning and Pollution Control* (Britain: Manchester University Press, 1976), 5.
[2] Christopher Wood, *Town Planning and Pollution Control,* 6.
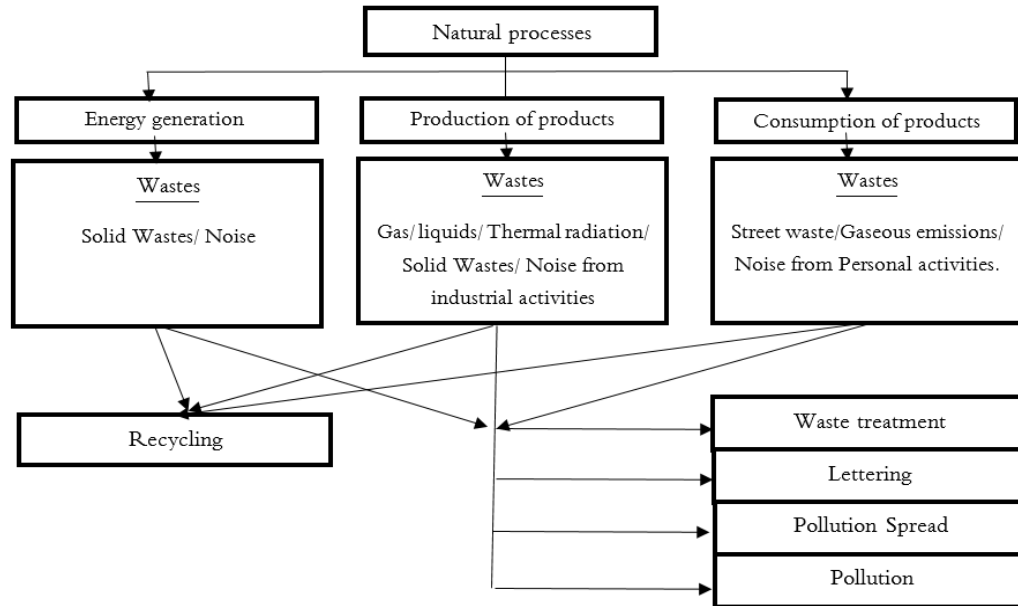
Figure (1.3): Pollution formation process

Source: Christopher Wood, *Town Planning and Pollution Control*, 7.

1.2.2. Pollution Types, Flows, Stocks and the Global Warming

1.2.2.1.Types of Pollution

Pollution has different types and shapes, some of which are famous but others are less frequently used. Its types are classified as follows:

> **Air Pollution**

Air pollution is defined as the condition in which air is contaminated by foreign elements. It creates gaseous pollutants like sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O_3), volatile organic compounds (VOC), hydrogen fluoride (HF), hydrogen sulfide (H_2S), in addition to solid and liquid substances that, when appearing in sufficient concentration, under certain conditions, and for a sufficient time, tend to threaten human health, welfare or safety, and cause environmental damage. These pollutants are emitted from large stationary sources such as smelters, fossil fuel, fired power plants, petroleum refineries, industrial boilers, and manufacturing facilities as well as from mobile

sources like vehicles. Air pollution causes ozone depletion, acid rain, photochemical smog…etc., and such phenomena cause diseases, such as heart diseases, asthma, respiratory infections…etc. The pollutants or contaminates of air pollution are divided into two basic categories:

❖ **The first type of contaminants**: termed as primary pollutants, are those which are generated directly from a certain process like the smoke emitted from the factories and vehicles.

❖ **The second type of pollutants:** are named as the secondary contaminates or pollutants and these are the ones, which are produced due to the reaction to natural air with primary pollutants.

The small size of particles is directly related to their potential for creating health problems. PM10 represents small particles where only less than 10 micrometers in diameter could pose the highest danger, because they can get deep into human lungs, and some may even get deeper into human bloodstream. The PM10 includes[1] "inhalable coarse particles" such as those found near dusty industries and roadways, which are smaller than 10 micrometers and larger than 2.5 micrometers in diameter; and "fine particles" such as those found in haze and smoke that are 2.5 micrometers in diameter at most. Particle pollution causes serious health problems. Many scientific studies have connected particle pollution exposure to a large range of problems, including[2]:

➢ Premature death in people with lung or heart disease,

➢ Nonfatal heart attacks and irregular heartbeat,

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[1] "Particulate Matter (PM) Pollution Share", United States Environmental Protection Agency (EPA), 2014, accessed May 3rd , 2014, https://www.epa.gov/pm-pollution
[2] Ibid.

➢   Serious asthma,

➢   Increased respiratory symptoms, such as coughing or difficulty in breathing

and irritation of the airways and, to a certain level, decreased lung function.

These particles can be carried over long distances by wind and then settle on water or

ground, the fact that make lakes and streams acidic, change the nutrient balance in large river

basins and coastal waters, deplete the nutrients in soil, damage farm crops and sensitive

forests and can even affect the diversity of ecosystems. Particle pollution can damage

different types of materials, including culturally and aesthetically important monuments,

statues and historical relics. The following figure shows the levels of PM10 around the world
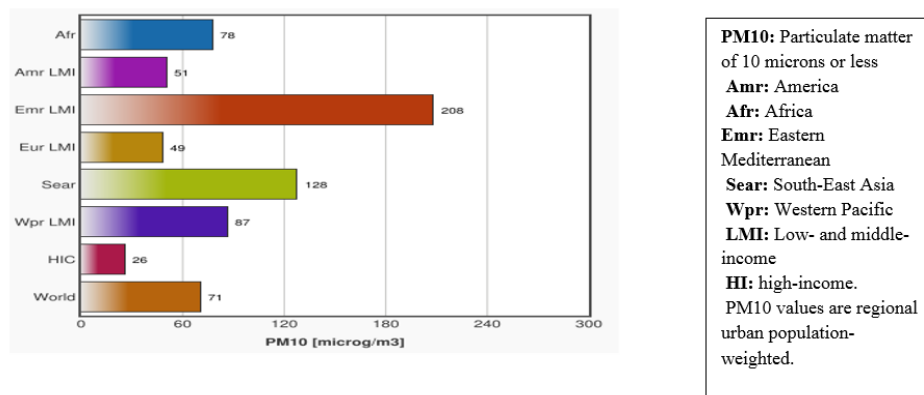
Figure (1.4): PM10 Levels by Region for the Period 2008- 2012

 Source: World Health Organization database, accessed May 20, 2014,

http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

The figure (1.4) contains results of ambient air pollution monitoring from almost

1600 cities in 91 countries wherein, air quality is represented by annual mean concentration

of particulate matter (PM10 and PM2.5, i.e. particles smaller than 10 or 2.5 microns). It is

clear that Eastern Mediterranean has the highest level of PM10, which is due to having the

largest desert in the world[1]. The Eastern Mediterranean is as one of the areas most affected by dust in the world. Dust or sand storms are caused by the outflow from low-pressure cells passing through the desert from west to east. Sand storms can occur throughout the year in that region, but the prime months are May-September. In addition to that, the huge number of petroleum companies working there extract fossil fuel and emit different types of pollutants into the air. All these make the air heavily polluted with the PM10[2].
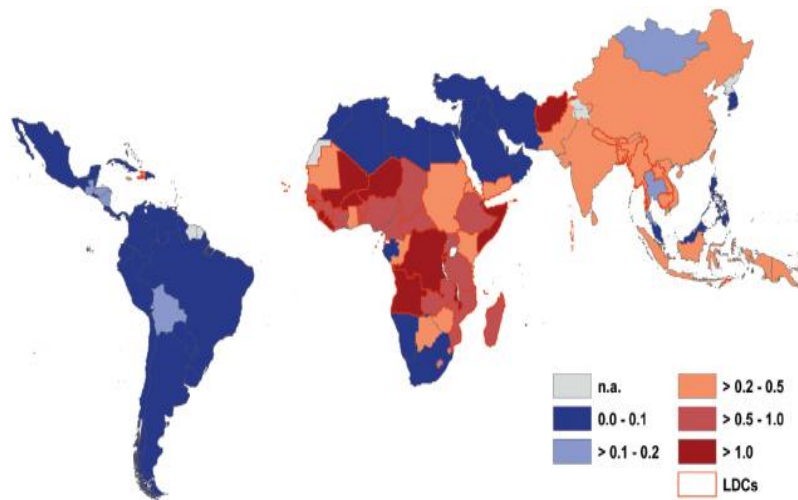
Figure (1.5): World Map of the Number of Deaths per 1000 Capita per year

Source: World Health Organization**,** accessed May 20, 2014, http://ourworldindata.org/data/environmental-change/indoor-air-pollution/

The figure above shows the number of deaths per 1000 capita per year attributable to indoor air pollution from solid fuel use.

➤ **Water Pollution**

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[1] Hasanean H.M., "Middle East Meteorology", Meteorology Department, UNESCO-EOLSS chapters, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdul-Aziz University, accessed January10, 2014, http://www.eolss.net/sample-chapters/c01/e6-158-19.pdf
[2] Ibid.

Water pollution is defined as the continuous addition of contaminants to the water bodies like oceans, lakes, rivers, and other inland waters resulting in the pollution of water. This makes the concerned water unusable unpotable. When water bodies are mixed with high degree of contaminants that harm aquatic species, plants, animals and other tiny creatures such as bacteria. The main role played in the pollution of water is by the several industrial wastes and chemicals that are thrown into the water bodies without acceptable treatment, and thus polluting the water. The high temperature fluids harmfully affect the thermal status of the water and cause changing in the color of natural clean water[1]. The list of the pollutants of water also includes many other elements such as cleaners being generated by the manufactories and also from the households which get mixed with the water bodies. Testing the level of water pollution can be done in a several ways, one of which is the physical testing that is based on analyzing the temperature, concentration of pollutants, solids and other factors for a specific sample of water.

➤ **Thermal Pollution**

The thermal pollution is defined as the increase in the temperature of a body of water which may be oceans, lakes, rivers or ponds. The basic source of this category of pollution is using water as a coolant in some industries which include the disposal or reducing of heat generated by the industrial processes to the water to help better produce their products and thus, cause the water temperature to increase. The thermal pollution affects the aquatic systems where the level of dissolved oxygen is readily declined by the sudden increase in the water's temperature harming the aquatic species' life. The reduction in the ecosystem oxygen

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[1] Hamblin, Jacob Darwin, *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age,* (New Jersey: Rutgers University Press, 2008), 59.

level is also witnessed due to the reduced lifespan of the primary producers. There are some other causes of thermal pollution that are as follow[1]:

- **Deforestation**: Plants and trees prevent sunlight from falling openly on rivers, ponds or lakes. Water bodies like lakes are openly exposed to sunlight when deforestation appears, thus raising its temperature by absorbing more heat. Deforestation is also a substantial cause of the higher concentrations and intensity of greenhouse gases i.e. global warming in the atmosphere.

- **Runoff from Paved Surfaces**: During summer seasons, the pavement and paved surfaces get quite hot creating warm runoffs, which gets into the water bodies and sewer systems.

- **Soil Erosion**: Constant soil erosion causes water bodies to rise in some areas, making them wide-open to sunlight. The high temperature could lead to fatality for aquatic biomes as it may increase anaerobic conditions.

- **Natural Causes**: Natural causes such as volcanoes and geothermal activity under the seas and oceans can trigger hot lava to raise water bodies' temperature. Lightening can as well introduce a massive volume of heat into the seas and oceans, which lead to significant impacts on the environment.

➢ **Soil Pollution**

Like all other forms of natural surroundings, soil also suffers from pollution. The soil pollution is defined as the contamination of soil with harmful materials that can adversely bung or affect the quality of the soil and the health of those living on it. The introduction of

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[1] "Sustainable management for European local ports, Pollution part 01 of 02 Overview", (2010),70, accessed May 24, 2014, http://www.seinemaritime.net/suports/uploads/files/Pollution%20E-book%20Part%201%20Overview.pdf

the contaminated particles to soil occurs due to both the human and natural activities wherein, the former play a main role. The most important factor leading to soil pollution is the interminably increasing number of construction sites in our world. That is usually carried out in the borders of urban areas, resulting the decomposed waste to mix with the nutrients existing in soil in the initial stages leading to its depletion. Soil pollution mainly happens due to industrial wastes, urban wastes, agricultural practices, radioactive pollutants and biological agents[1]. The polluted soil directly affects the human health and well-being either through the direct interaction with it or by the breathing of harmful soil pollutants which are vaporized.

➢ **Noise Pollution**

Noise pollution is defined by Merriam Webster dictionary as "loud or unpleasant noise that is caused by automobiles, airplanes, etc. and that is harmful or annoying to the people who can hear it[2]". The basic sources of this type of pollution are the machines that are widely found in the transportation systems and industries. Also, the loud noise resulted by loud music and other building activities can also participate to this pollution leading to some diseases that threaten the health or welfare of human or animal inhabitants. Additional noise pollution is contributed by office apparatuses, power tools, sirens and other equipment. The concept of noise pollution is a very special one and the sound is something which has the ability to have both bad and good effects on the human health. Undesirable noises, in the form of noise pollution, can cause many health harms and problems, but at the same time some soothing or calming sounds can have a positive effect on the mental as well

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[1] Ibrahim A. *Mirsal, Soil Pollution: Origin, Monitoring & Remediation*, 2nd edition, (Berlin: Springer, 2008), 4.
[2] Merriam-Webster English Dictionary, s.v., "Noise Pollution", accessed May 14, 2015,http://www.merriam-webster.com/dictionary/noise%20pollution

as physical human health. Noise pollution is not simple to measure, because the concept of noise depends on the context of the sound and the subjective consequence it has on the people hearing it.[1]

<div align="center">

1.2.2.2.Pollution Flows and Pollution Stocks

</div>

Some proportion of the emission that flow form economic activities is quickly absorbed and transformed by environmental media into harmless forms. However, carrying capacity will often be insufficient to deal with all wastes in this way. This implies that some proportion of wastes will, in any time interval, remain unabsorbed or untransformed. These may cause damage at the time of their emission, and may also, by accumulating as pollutant stocks, cause additional future damage. The decay of stocks of pollutants is often very slow. The half-lives of some radioactive substances are thousands of years, while some highly persistent pollutants, such as the heavy metals, the rate of decay is approximately zero[2].
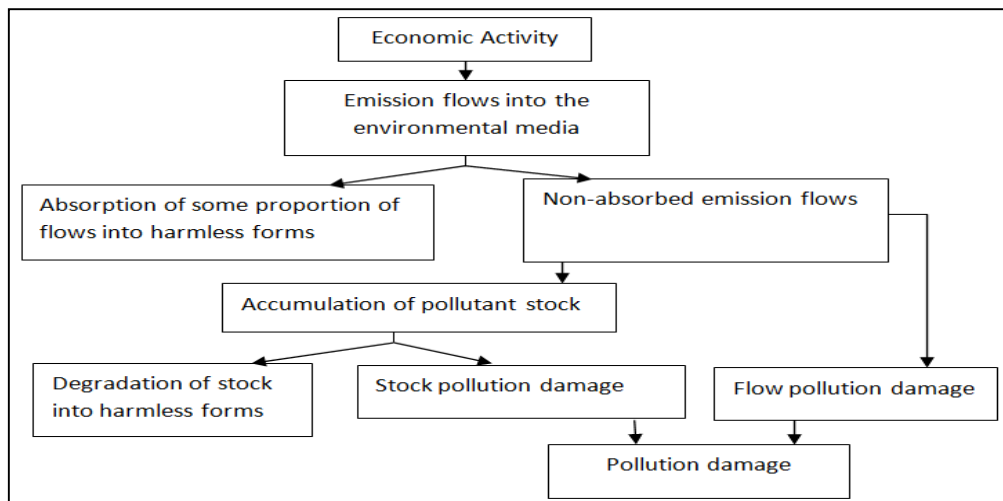
Figure (1.6): Economic Activity, Residual Flows and Environmental Damage

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[1] Birgitta Berglund, Thomas Lindvall, Dietrich H Schwela ,"Guidelines for Community Noise," World Health Organization, 1995, accessed May 20, 2014 http://www.who.int/docstore/peh/noise/Comnoise-1.pdf

[2] Roger Perman , Yue Ma ,James Mcgilvray , Michael common , *Natural Resource and environmental economics*, 3rd edition(UK: Pearson Education Limited, 2003), 168.

Source: Roger Perman, et al, *Natural Resource and Environmental Economics*, 169.

Pollution can be classified in terms of its damage mechanisms. This has important implications for how pollution targets are set and for the way in which pollution is most appropriately controlled. The distinction here concerns whether the damage arises from the flow of pollutants or from the stocks of pollution in the relevant environmental medium. These terms are defined as follows[1]:

❖ **Flow-damage pollution:** It occurs when damage results only from the flow of residuals; that is, the rate at which they are being discharged into the environmental system. This corresponds to the right hand side branch in Figure 1.6. By definition, for pure cases of flow-damage pollution, the damage will instantaneously drop to zero if the emissions flow becomes zero. This can only be exactly true when the pollutant exists in an energy form such as noise or light so that when the energy emission is terminated no residuals remain in existence. However, this characterization of damages may be approximately true in a wider variety of cases, particularly when the residuals have very short life spans before being transformed into benign forms.

❖ **Stock-damage pollution:** It describes the case in which damages depend only on the stock of the pollutant in the relevant environmental system at any point in time. This corresponds to the central branch in Figure 1.6. In order for a stock of the pollutant to accumulate, it is necessary that the residuals have a positive lifespan and that emissions are being produced at a rate which exceeds the assimilative capacity of the environment. An extreme case is that in which the assimilative capacity is zero, as seems to be approximately the case for some synthetic chemicals and a number of heavy metals. The

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[1] Ibid., 170.

left-hand branch in Figure 1.6 does not then exist. Metals such as mercury or lead accumulate in soils, aquifers and biological stocks, and subsequently in the human body, causing major damage to human health.

1.2.2.3.Global warming

The increasing "Greenhouse Gases" (GHG) emissions from fossil fuels consumption are linked to the economic development of a country. It is essential to know about GHG emissions and climate change thoroughly.

➢ **Greenhouse Gases**

There exists a balanced natural system, known as greenhouse effect that regulates temperature on the earth. The anthropogenic activities can upset this balanced natural system by releasing heat trapping GHGs in the atmosphere. The human induced enhanced-greenhouse-effect causes environmental concerns in terms of global warming and climate change. The major sources of these gases include industrial processes, fossil fuel combustion for power generation, transportation, burning of the forests, agricultural activities, changes in land use…[1]etc.

All forms of burning results into ultimate emission of carbon dioxide (CO2) gas, which has a high potential GHG. The partial combustion of burning also emits certain gases such as, oxides of nitrogen (NOx) and carbon monoxide (CO) which can react with other gases in the atmosphere to form to the ozone–another GHG. Water vapor, CO2, methane (CH4), Nitrous oxide (N2O) and ozone are considered to be direct GHGs while CO, Fluorocarbons (CFCs, HFCs, and SF6etc.), Oxides of Sulphur (SOx), hydrocarbons and NOx as indirect GHGs. Although water vapor is the most important GHG, its concentration is not

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[1] Rao Y. Surampalli et al, *Climate Change Modeling, Mitigation and Adaptation*, (USA: American Society of Civil Engineers, 2013), 11.

influenced extensively by direct anthropogenic emissions. However, water vapor intensifies warming of the atmosphere as the atmosphere holds more water vapor while warming. But, water vapor is of natural origin and human activities do not affect its concentrations directly[1].

CO_2 contributes the highest proportion of greenhouse effect mainly because of its higher concentration in the atmosphere. Followed by Chlorofluorocarbons (CFCs), which although present in low concentrations, are very strong greenhouse gases. Anthropogenic emissions of CO_2, CH_4, CFCs and N_2O are the key contributors to the enhanced greenhouse effect[2]. When complex photochemical reactions occur amongst several pollutants, it leads to formation of tropospheric ozone, which may be a significant GHG, but not globally quantified at present.

These GHGs also have direct negative impacts on the ecosystem and human health. The increase in CO_2 concentration in the atmosphere has a major share (over half) of the enhanced greenhouse effect. The rest of it is shared mainly by the increase in concentrations of halocarbons and CH_4. Annual emissions of CO_2 have grown from 21 to 38 GT from 1970 to 2004.

➢ **Role of GHGs in Climate Change**

The entire climate system, atmospheric chemistry and life on earth are driven mainly by incident solar radiation. While 30% solar radiation reflects back to the space, the remaining 70% is absorbed by the surface atmospheric system which leads to the heating effect of the atmosphere. When the surface and atmosphere become warm, the infrared radiation is emitted. It is also called the long wave radiation.

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[1]Ibid.
[2] Ibid., 12.

The process of net incoming solar energy (i.e., downward solar energy lessen the reflected) and outgoing heat radiation from the warmer planet which escapes to space will continue until the two energy components are in balance. This energy balance of radiation provides a strong constraint on the global average temperature of the planet. GHGs absorb and emit long wave radiation, while aerosols absorb and scatter solar radiation. Large size aerosols also absorb and emit long wave radiation, but this process is not significant for the smaller human induced aerosols[1].
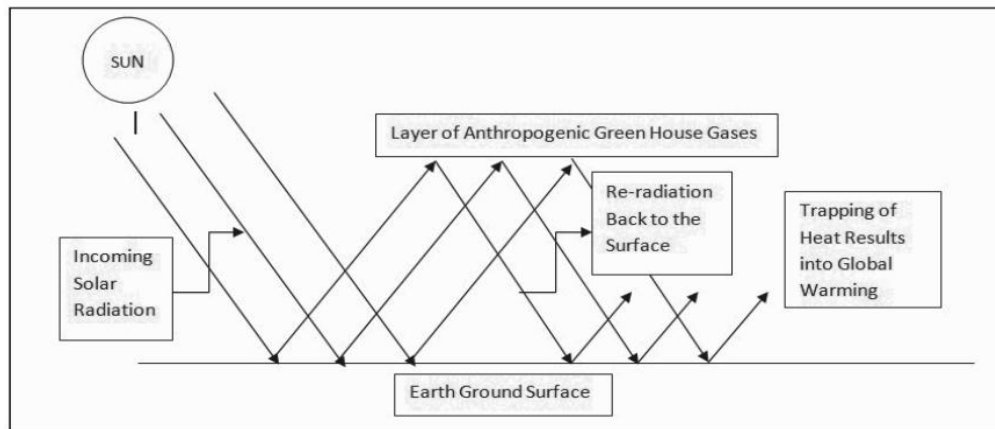
Figure (1.7): GHGs and Climate Change through Global Warming

Source: Rao Y. Surampalli et al, *Climate Change Modeling, Mitigation, and Adaptation, 13.*

As shown in Figure 1.7, the trapping of long wave radiation can be explained well by principles of quantum mechanics. The oxygen atoms vibrate with carbon atoms in center.

The frequency of this vibration matches with some of the long wave radiations from the earth surface and the atmosphere, resulting in absorption of radiation by GHGs. These gases colloid with other air molecules, converting trapped radiation into heat that is given back to the Earth's surface. As the concentration of GHGs increases in the atmosphere, the

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[1] Ibid., 13.

infrared layer also becomes thicker resulting in an accumulation of excess energy on the planet. The planetary system gets rid of this excess energy by warming and emitting excess infrared radiations until the surface atmosphere system is in balance. When variations in components of the climatic system takes place, it results in climatic change.

The climatic system has five components coupled with each other, namely, atmosphere, land, ocean, ice and biosphere. Atmospheric processes strongly interact with other components of the climate system giving rise to climate change. Particularly, energy from the sun is the driving force in the climatic system. Greenhouse effect causes significant changes in other components of the climatic system, resulting in climate change. Accordingly, climate change refers to the undermining impact on climate and weather patterns. Increased severe weather conditions like draughts, storms, floods, change in the ecosystem, loss of animal and plant species, stresses to human health, and alterations in regional agricultural productivity are accompanied with very small changes in average atmospheric temperatures. Hence, it is very important to establish a good link between GHGs and climate change to make value judgments for limiting the effects[1].
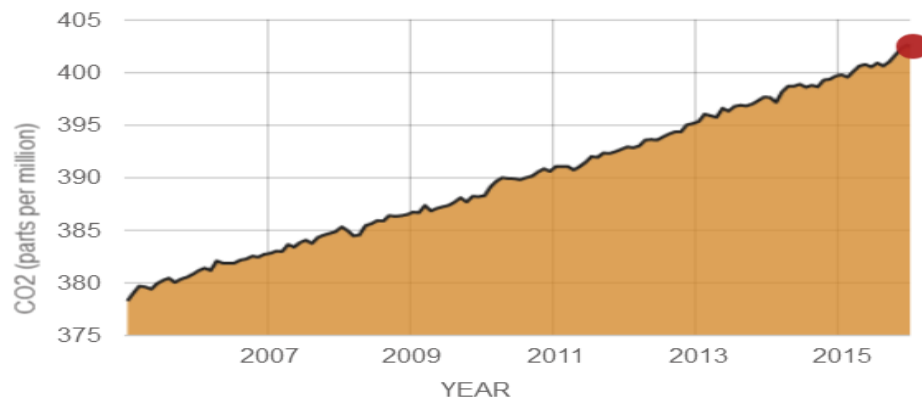
Figure (1.8): Atmospheric CO_2 levels in recent years
Source: Global climate change, vital signs of the planet, accessed May 21, 2014, *http://climate.nasa.gov/vital-signs/carbon-dioxide/*

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[1] Ibid., 14.

The above chart shows atmospheric CO_2 levels in recent years, with average seasonal cycle removed.

1.2.3. The Economic Measurement of Pollution, Its Impact Assessment and Control Tools

1.2.3.1. The Economic Measurement of Pollution

The environmental pollution resulted from human activities is considered as a negative externality; a term that has its own measurement way as follows:

➢ **Externalities**

An externality, is said to occur when the production or consumption decisions of one agent have an impact on the utility or profit of another agent in an unintended way, and when no compensation payment is made by the generator of the impact to the affected party. Also the OECD defined the externalities as the situations when the effect of production or consumption of goods and services imposes costs or benefits on others[1], without appropriate monetary compensation occurring, or they are not reflected in the prices charged for the goods and services being provided. An externality is positive if some agent's behavior makes another agent better off, and it is negative if some agent's behavior makes another agent worse[2].

When a "Negative Externality" exists, the price of goods and services does not reflect the full marginal social costs of resources allocated to their production. There is an extra cost to third parties referred to as the marginal external cost (MEC). This is the extra cost to the third parties of the production of another unit of the goods producing the negative externality.

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[1] OECD Glossary of Statistical Terms , s.v., "Externalities",   accessed May 15th, 2015, http://stats.oecd.org/glossary/detail.asp?ID=3215
[2] John Leach, *A course in public economics*, (UK: Cambridge university press, 2004), 241.

MEC is a true incremental cost that is not included in the price, whereas MPC refers to Marginal Private Cost, MSC refers to Marginal Social Cost. The curve is on MPC, which does not reflect the negative externalities. Therefore, this creates the welfare loss which is colored in black in the middle of the next graph.
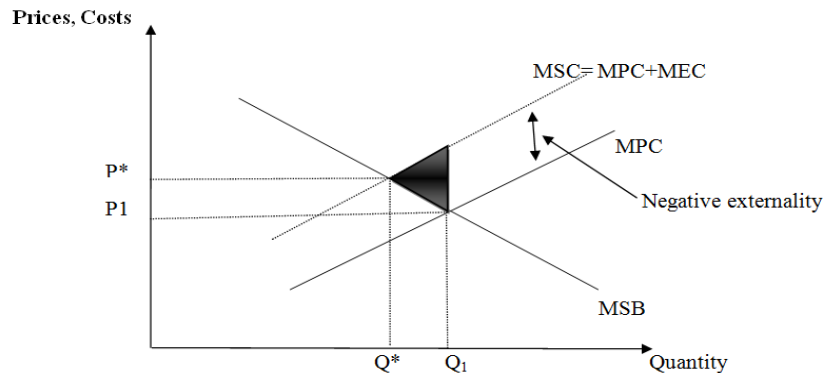
Figure (1. 9): The Negative Externalities

Source : Sylvie Faucheux, Jean François Noël, *Economics of Natural Resources and Environments,* (Paris, 1996). 181.

➢ **Cross-Border Externalities**

A cross-border externality occurs when actions of one country have consequences on another country, unmediated by classically competitive markets. Examples of negative cross-border externalities are: water use in countries that share rivers and water streams, atmospheric pollution, epidemics, financial contagion, and the spillover effects of civil wars[1].

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[1] Ravi Kanbur, "Cross-Border Externalities, International Public Goods and Their Implications for Aid Agencies", NewYork, Cornell University, 2001, 02, accessed May 24th , 2014, http://kanbur.dyson.cornell.edu/papers/IPGWB.pdf

1.2.3.2.Assessment Methods of Environmental Impact

➢ **The Concept of Environmental Impact Assessment (EIA)**

Environmental Impact Assessment is defined by The International Association for Impact Assessment (lAIA) as the procedure of identifying, forecasting, evaluating and mitigating or reducing the social, biophysical and other related effects of development proposals prior to major decisions being taken and commitments made.

Environmental Impact Assessment or "EIA" is a tool or (activity) which identifies, forecasts, interprets and communicates information, and proposes ameliorative measures, about impacts of a proposed action or development proposal on human health and the well-being of the ecosystem upon which human survival depends[1].

❖ **EIA Methodologies:** The EIA methodology uses the following tools:

✓ **Checklists**: Useful for identifying key impacts and ensuring that they are not overlooked, especially in scoping. It can include information such as data requirements, study options, questions to be answered and statutory thresholds, but it is not generally suitable for detailed analysis[2].

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[1] Alan Gilpin, "Environmental Impact Assessment", Cambridge University Press, UK, 1994, P16.
[2] *S. Chieng, "Environmental Impact Assessment", 29,* accessed May 24th, 2014 *https://www.ece.ubc.ca/~leos/pdf/a230/notes/t2/EIA.pdf*

```
Proposed project activities          Yes        No
    •dredging
    •blasting
    •pier construction
    •traffic diversion

Affected physical components
    •water quantity
    •water quality
    •soil quality
    •soil stability
    •air quality
Affected biological components
    •fish populations
    •spawning habitat
    •bird habitat
    •wildlife habitat
Affected socio-economic components
    •employment
    •noise

    •health
```

Figure (1.10): Sample Checklist for Bridge Construction Project

Source: S. Chieng, "Environmental Impact Assessment", 29, accessed May 24th, 2014,

https://www.ece.ubc.ca/~leos/pdf/a230/notes/t2/EIA.pdf

✓ **Matrices:** Mainly used for influence identification, however they provide the facility to
show cause-effect links between impact causes plotted along one axis and impacts plotted
along the other axis. They can also indicate features of impacts such as their predicted
magnitudes and whether they are likely to be localized or extensive, on long or short term
etc. There are deferent dimensional tables used to identify the impact arising from the
interaction between project activities and specific environmental components, such as the
two-dimensional tables. Notable matrices include Leopold Matrix, Peterson Matrix,
Component Interaction Matrix…etc.

The following figures show tow and three-dimensional matrices
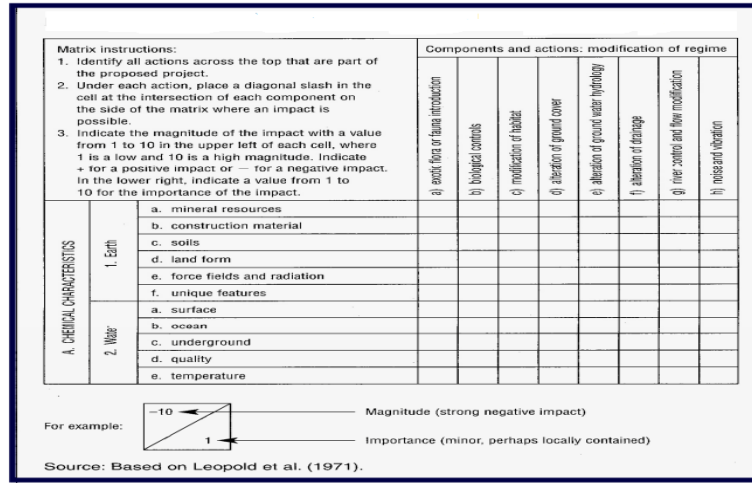
Figure (1-11): Example of a Section of the Leopold Matrix

Source: S. Chieng, "Environmental Impact Assessment", 30.
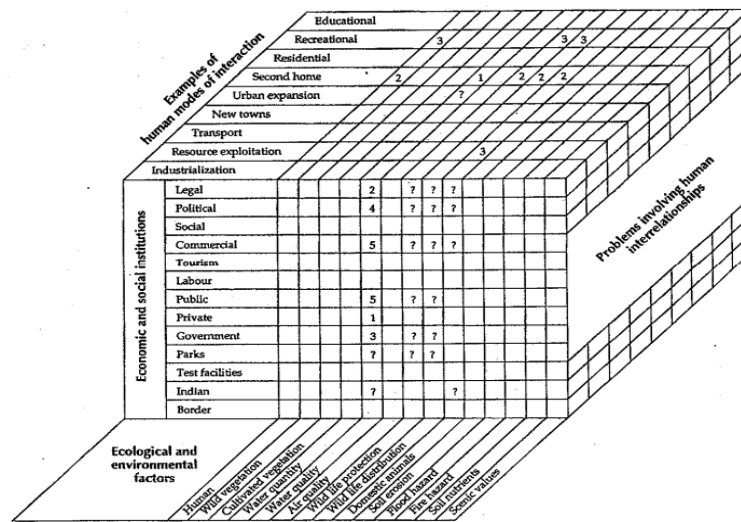
Figure (1.12): Sample of a Three-Dimensional Impact Matrix

Source: S. Chieng, "Environmental Impact Assessment", 31.

- ✓ **Flowcharts and Networks:** Can be useful for identifying cause-effect relationships/links/path ways: between impact sources, between sources and impacts, and between primary and secondary impacts[1].

- ✓ **Mathematical/ Statistical Models:** Based on mathematical or statistical functions which are applied to calculate deterministic or probabilistic quantitative values from numerical input data. They range from simple forms that can be employed using a calculator or computer spreadsheet, to sophisticated computer models that incorporate many variables. They need adequate/ reliable data and their results require validation.

Maps and GIS: Maps can indicate feature such as impact areas, locations and extents of receptor sites. Overlay maps can combine and integrate two or three "layers", e.g. for different impacts and/or environmental components or receptors. Geographic Information Systems (GIS) field is probably the hardest to answer in a succinct and clear manner. GIS is a technological field that incorporates geographical features with tabular data in order to map, analyze and assess real-world problems[2]. GIS can analyze a number of layers, and has facilities for the input and manipulation of quantitative data, including modelling.

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[1] S. Chieng, "Environmental Impact Assessment", 36, accessed May 24th, 2014, https://www.ece.ubc.ca/~leos/pdf/a230/notes/t2/EIA.pdf

[2] David J. Bodenhamer, John Corrigan, Trevor M. Harris, *The Spatial Humanities: GIS and the Future of Humanities Scholarship*, (USA: Indiana University Press, 2010), 31.

1.2.3.3.The Economic Tools of Pollution Control

The economic tools designed for pollution control are based on the merge of negative externalities resulted by economic activities and the economic tools such as taxes, subsidies and tradable permits to reduce pollution.

➢ **The Environmental Taxation and Subsidies**

❖ **Environmental taxation (Green Taxes) for pollution control**

Taxation has an important role to play in protecting the environment by helping incorporate the costs of environmental damage into the prices of goods, services or activities which give rise to environmental damage. An environmental tax is a physical unit (or a proxy of it) of something that has a proven, specific negative impact on the environment, in a situation where the production or consumption of some goods or services results in a negative external effect. Then social welfare can be improved by imposing a tax on the good or service. This approach was conceived by Pigou and formalized by Baumol (one of much formalization). It seeks to calculate a damage function for different rates of emission of the pollutant, and then to equate the marginal net private benefit (MNPB) of the activity causing the pollution with the marginal external cost (MEC). The equality is achieved by imposing a tax equal to the difference between them at the optimal emission level. The figure below sets out this basic theoretical position, in which Q is the no tax pollution level of production and Q* is the optimal pollution level. The optimal tax is then t*. The theory of environmental taxation has been much developed to take into account market situations other than perfect competition and other considerations[1]. (Good price= marginal social cost = marginal private cost + Tax)

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[1] Carlo Carraro, Domenico Siniscalco, *New Directions in the Economic Theory of the Environment*, (UK: Cambridge University press, 2009), 82.
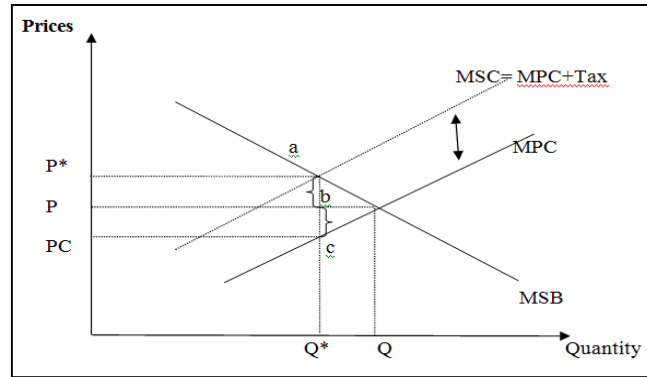
Figure (1.13): The Impact of Environmental Taxes on Prices and Production Quantities.

Source: Carlo Carraro, Domenico Siniscalco, *New Directions in the Economic Theory of the Environment,* 83.

From Figure (1.13) above, it is clear that the quantity of production decreases from Q to Q*. Goods price also increases from p to p* because of tax. The burden of tax will be borne by both the producer and consumer. Whereas, the consumer pays the value "ab" and the producer pays the "bc". Without government intervention, there is no market incentive for firms and households to take into account environmental damage, since its impact is spread across many people and it has little or no direct cost to the polluter. Therefore, protection of the environment generally requires collective action, usually led by government. Environmental taxes have many important advantages, such as environmental effectiveness, economic efficiency, the ability to raise public revenue and transparency. Also, environmental taxes have been successfully used to address a wide range of issues including waste disposal, water pollution and air emissions. Regardless of the policy area, the design

of environmental taxes and political economy considerations in their implementation are crucial determinants of their overall success[1].

➢ **Subsidies for Pollution Control**

Subsidies for pollution control involve financial support by government for activities believed to be environmentally friendly. The types of subsidies described like low-interest loans, favorable tax treatment and procurement mandates for products are believed to have environmental advantages research, development, information dissemination and others. Subsidies are often funded by the fees charged on environmentally harmful products or activities. Advance disposal fees, for example, provide revenues to subsidize the proper disposal of products after their use. Although it could be argued that such disposal activities are not truly subsidized by the government if they are funded entirely by the fees on the product that are paid by industry or consumers. For more clarity we take the USA subsidy instruments as an example. Table (1-2) summarizes various subsidy instruments in USA. Column 2 shows who pays for the various subsidies. The issue of whether the costs of subsidies are passed onto other businesses or consumers in some way is not addressed. Information on funding sources other than general revenues is also included in parentheses, where available. Column 3 lists the recipients of these subsidies[2].

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[1] Carlo Carraro, Domenico Siniscalco, *New Directions in the Economic Theory of the Environment,* 83.

[2] "Subsidies for Pollution Control", The U. S. Experience with Economic Incentives for Protecting the Environment, (2001), 111, accessed May 24th, 2014, http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0216B-08.pdf/$file/EE-0216B-08.pdf

Table (1.2): The Use of Subsidies in Environmental Management

SUBSIDY INSTRUMENT	WHO PAYS?	RECIPIENTS
Grants	.	
Brownfields development grants	EPA, states	Communities, property owners
Cost sharing for land conservation	Federal government	Property owners
Conservation easements	Federal, state, and local governments (Land transfer taxes)	Property owners
Environmental violation reporting rewards	States of New Jersey, California	Individuals and organizations
Waste management and recycling grants	Federal, state, and local governments (advance disposal fees (ADFs), waste taxes)	Public and private organizations
Unit-based waste collection or reuse payments	State governments (ADFs, waste taxes)	Businesses
Unit-based payments for the use of alternative fuel vehicles (AFVs)	Federal government	Public bus systems and small businesses
Municipal sewage treatment plant construction grants (replaced by loans)	Federal and state governments	Communities
Loans	.	.
Pollution control loans	State governments	Small businesses

Recycling business loans	State governments (ADFs, waste taxes)	Businesses
Municipal sewage treatment plant construction loans (replaced previous grant program)	Federal and state governments	Communities
Tax Benefits	.	.
Pollution control property	State governments	Private organizations
Louisiana environmental score-card deduction	State of Louisiana	Businesses
Brownfields development	State governments	Property owners
Land use credits	State governments	Property owners
Recycling benefits	State governments	Businesses
Credits for ethanol and compressed natural gas	Federal and state governments	Alternative fuel vehicle manufacturers
Credits for alternative fuel vehicles and equipment	Federal and state governments	Alternative fuel vehicle purchasers
Renewable electricity generation credits	Federal government	Businesses
Electric vehicle credits	Federal government	Businesses or organizations
Interest exemption of pollution control investment debt	Federal government	Businesses or organizations
Procurement Mandates	.	.

Public procurement of recycled products	Federal, state, and local governments	Recycled products manufacturers
Public procurement of alternative fuel vehicles	Federal, state, and local governments	Alternative fuel vehicle manufacturers
Recycled content requirements	Private organizations	Recycled products manufacturers
Mandates for the use of alternative fuel vehicles	Private organizations	Alternative fuel vehicle manufacturers

Miscellaneous		
Reduced fines in return for supplemental environmental projects	Federal and state governments	Businesses
Accelerated review of applications for new pesticides	Federal government	Pesticide manufacturers
Relaxed regulatory requirements (e.g., ethanol Ried Vapor Pressure (RVP) waiver)	Federal, state, and local governments	Various organizations
Research & development; public education (technical assistance to participants in voluntary programs)	Federal, state, and local governments	Various organizations

Source: The U. S. Experience with Economic Incentives for Protecting the Environment, "Subsidies for Pollution Control", 111.

➢ **Marketable Pollution Permits**

As with command and control tax/ subsidy instruments, marketable permits (also known as tradable or transferable permits). The idea of pollution permits was introduced by J.H. Dales, as with standard-setting, the regulating authority allows only a certain level of pollutant emissions, and issues permits (also known as pollution "consents" or certificates) for this amount. However whereas standard-setting ends there, the pollution permits are tradable, they can be bought and sold on a permit market[1].

Marketable permit systems are based on the principle that any increase in emission must be offset by an equivalent decrease elsewhere. There is a limit set on the total quantity of emissions allowed, but the regulator does not attempt to determine how that total allowed quantity is allocated among individual sources[2]. Figure 1-14 illustrates the basic elements of marketable permits.

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[1]Jacqueline Murray Brux, *Economic Issues and Policy*, 6th edition, (USA: University of Wisconsin-River falls), 2015, 65.

[2] Roger Perman, et al, *Natural Resource and Environmental Economics*, 172.
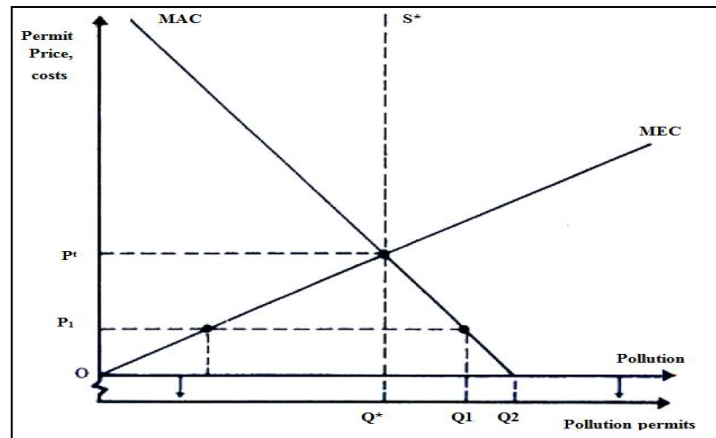
Figure (1.14): The Basic Analytics of Marketable Permits

Source: Marketable Pollution Permit, accessed May 25th, 2014 *https://dspace.ist.utl.pt/bitstream/2295/172618/1/ch8.pdf* .

Based on Figure 1.14 above, MAC is the marginal abatement cost curve. The horizontal axis shows the level of emissions and the number of permits .The easiest assumption to make is that one permit is needed for each unit of emission of pollution. The optimal number of permits is OQ* and their optimal price is OP*. That is, if they seek a Pareto optimum (Pareto optimum occurs if resources can be better utilized so that one group's prosperity increases, but not at the expense of another's) the authorities should issue OQ* permits. S* shows the supply curve of the permit; their issue is regulated and is assumed not to be responsive to price. The MAC curve is in fact the demand curve for permits. At the permit price P_1, for example, the polluter will buy OQ_1 permits. He does this because, in terms of control strategies, it is cheaper to abate pollution from Q_2 back to Q_1 than to buy permits. To the left of Q_1, however, it is cheaper to buy permits than to abate pollution. So as long as a market for the permits exists, firms will buy the permits as long as the price of the permit is less than their marginal abatement cost, until P=MAC (marginal abatement cost)[1].

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[1] Jacqueline Murray Brux, *Economic Issues and Policy*, 67.

1.3. The International Environmental Conventions

Over the twentieth century the world system signed a group of treaties and protocols to maintain the environment from the violations and the damage sustained by human activities.

1.3.1.   The Development of International Environmental Policy

The role of international law in protecting the environment is not necessarily different from domestic environmental law. Mainly, with regard to constitutional role, international law provides mechanisms and procedures for negotiating the necessary rules and standards, settling disputes, and supervising implementation and compliance with treaties and customary rules. In this context, it facilitates and promotes cooperation between countries, international organizations and constitutes the processes of international environmental governance. Moreover, Non- Governmental Organizations (NGO) participation have influenced environmental treaty negotiations. The purposes of "International Environmental Policy" are addressed as follows:

- ➢ **Regulating Environmental Problems**: Similar to national environmental law, the majority of international environmental law is concerned with regulating environmental problems, providing common standards and practices to prevent pollution, or stimulate conservation and sustainable use of natural resources and biodiversity. A flexible rule-making process allows easy and regular improvement in the light of technological developments and advances in science and other fields[1]. Most of this regulatory system is based on bilateral treaties, however, soft-law instruments, including codes of conduct, guidelines and recommendations are also employed. The so-called framework agreements allow successive

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[1] Patricia Birnie, Alan Boyle, Catherine Redgwell, *International Law and the Environment*, Third edition, (Great Britain: Oxford University press, 2009), 09-10.

negotiation of additional protocols, annexes and decisions of the parties to create an increasingly more detailed regulatory system.

➢ **Harmonization of National Laws with International Agreements**: another purpose of some international environmental agreements is to harmonize national laws, either internationally or regionally. Treaties on civil liability for nuclear accidents or oil-pollution damage at sea both afford good examples of such harmonization. Indeed, national law will fundamentally have to reproduce the provisions of these treaties similarly in each country. Hence, the main objective is to facilitate access to justice for litigants who have suffered loss in large-scale international accidents. When seeking to harmonize national law, regulatory treaties have different objectives. Implementing environmental protection procedures in economy might stimulate countries to participate in treaties when they are assured that the same regulatory standards will succeed in competitor countries. This will not always be possible, because developing countries often insist on different standards. However, the mere fact is that if certain countries have become members to a treaty, promising to take measures to deal with some environmental problems, this does not ensure, or necessarily promote, harmonization of national law for multiple reasons.

➢ **Flexibility:** to secure international agreement, flexibility is often the price which has to be paid. This has been true of agreements regarding land-based sources of marine pollution and dumping at sea. But greater harmonization might also be undesirable because environmental problems require flexible solutions while a treaty with precise rules might be hard to renegotiate, therefore it is too inflexible to respond to changing conditions. Consequently, most environmental treaties tend to lay down only general

principles, leaving the detailed standards to annexes which can be easily modified or complemented by new annexes provided that all the parties agree.

➢ **Compensation for Environmental Damage**: As a final point, reestablishment of or compensation for environmental damage is a more limited, but still important function of the international legal system. It is more limited because (1) only those who suffer from damage can secure such reparation, whether they are countries relying on the international law of state responsibility, or individuals relying on their right to bring trans boundary actions in national law, (2) and because not all environmental damage is necessarily capable of reestablishment or has an economically assessable value[1].

1.3.1.1. Sources of Binding International Environmental Law

Practitioners are normally associated with international environmental law treaties, since the mechanisms for global agreements take a wide variety of forms, ranging from bilateral to regional and global scopes. Any international environmental issue might implicate agreements at more than one level, therefore it is important for practitioners to understand the different types of agreements and how they interact[2].

- **Bilateral Agreements**

Bilateral agreements are enforceable agreements between two states. In the environmental field, they are frequently signed between two neighboring countries in relation to a shared natural resource such as a shared river. These agreements impose binding obligations on the parties, which in turn might impose obligations on private actors within their territory through implementing laws domestically. The small number of potentially

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[1] Ibid., 12.

[2] Roger R. Martella Jr. and J. Brett Grosko, *International Environmental Law, the Practitioners guide to the laws of the planet,* Section of Environment Energy and Resource, First Edition, (United States of America: American bar association, 2015), 968.

relevant bilateral agreements can pose a challenge, since practitioners might observe that

many of the bilateral agreements are relatively unknown or inactive. However, obligations

under the agreement are still effective as long as the agreement has not been replaced by

subsequent agreements in force between those parties.

- **Regional Agreements**

Regional agreements might be independent systems that are personalized to the

unique environmental circumstances of a given region. For instance, the regional seas

agreement is adopted under United Nation Environment Program (UNEP), such as the

Convention for the Protection and Development of the Marine Environment of the Wider

Caribbean Region and its protocols[1]. However, their obligations are distinct from obligations

set out in the Convention itself. Their agreements are slightly different from global

agreements especially when the regional agreement serves as a model for the subsequent

global agreement. For instance, the Protocol on Persistent Organic Pollutants to the

Convention on Long-Range Transboundary Air Pollution (LRTAP Protocol) is related to this

case. Although their basic structure and function is very similar, there are subtle distinctions

among the obligations in each agreement as well as in the lists of chemicals that they cover[2].

- **Global Multilateral Environmental Agreements**

Global multilateral environmental agreements (MEAs) are the most famous part of

the international environmental law ecosystem. These treaties might take different forms,

such as "convention," "treaty," "agreement," "charter," "final act," "pact," "accord,"

"covenant," "protocol," or "constitution" (for an international organization). As a principle,

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[1] *Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region*, U.S, Mar 24, 1983, LEXIS 254.
[2] PIC and POPs and the LRTAP POPs Protocol Implementation Act, H.R. Rep. No. 109-668 (2006), available at http://www.gpo.gov/fdsys/pkg/CRPT-109hrpt668/html/CRPT-109hrpt668.htm

international law, usually binds only those countries which have agreed to be bound by the

MEA. However, an MEA can affect non-Parties. For the countries which have only signed

and have not ratified yet, they are nonetheless expected to not do anything that will affect the

aims and purposes of the MEA. They are not declarations of intention (which are non-

binding); they are rules of law. As such, they are a powerful tool for the implementation of

policies directed at environmental protection and sustainable development goals. MEAs must

conform to the international public law[1]. Legally binding and non-legally binding agreements

come in many shapes and forms. They can be of the following types or denominated as

follows:

Table (1.3): Forms of Binding and Non-Legally Binding Agreements

Legally binding (MEAs)		Non-Legally binding
Treaties	Accords	Resolutions
Conventions	Pacts	Decisions
Agreements	Charters	Declarations
Protocols	Amendments	Recommendations

Source: United Nations Environment Program, accessed May 25th, 2014

http://www.unep.org/delc/Portals/119/audingmeas.pdf

1.3.2. Main International Environmental Agreements

Many international environmental conventions have been signed for protecting our globe,

in this context the main environmental conventions and the climate change conventions are

addressed as follows:

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[1] United Nations Environment Program, AUDITING THE IMPLEMENTATION OF MULTILATERAL ENVIRONMENTAL AGREEMENTS (MEAs): A PRIMER FOR AUDITORS, P 05 http://www.unep.org/delc/Portals/119/audingmeas.pdf

➢ **The 1972 United Nations Conference on the Human Environment**

The United Nations Conference on the Human Environment (Stockholm Conference), was held in June 1972. This event turned the environment into a major issue at the international level. The conference drew together developed and developing countries[1], however some countries such the Soviet Union and most of its allies did not attend it. The Stockholm conference produced a declaration of 26 principles and an action plan of 109 recommendations. The Stockholm declaration on the human environment and principles constituted the first body of "soft law" in international environmental affairs.

The Conference resulted in four major initiatives at the normative, institutional, programmatic, and financial levels, which together provided the driving force for developments in the UN during the next decade and beyond[2]. The first was the adoption of the Stockholm Declaration on the Human Environment, intended to inspire and guide the peoples of the world in the preservation and enhancement of the human environment[3]. The second was the establishment of a new institution within the UN, which is the UN Environment Program (UNEP). The third was the adoption of an Action Plan for the development of environmental policy, to be administered by UNEP. The fourth was the institution, by voluntary contributions, and Environment Fund. The key normative provision in the Stockholm Declaration, Principle 21, is purportedly drawn from existing treaty and

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[1] J haveri, Gupta, and Ott, *Assessing and Explaining LRTAP Implementation and Effectiveness The LRTAP Convention/Second Sulphur Protocol: Possible Lessons for the Climate Convention,* (IIASA Working Paper, 1996)

[2] *Together with the Action Plan,* The Report of the Conference on the Human Environment, is found in UN Doc A/CONF 48/14/Rev 1 (1972).

[3] Reports of the Preparatory Committee relevant to the Declaration are in UN Doc A/CONF 48/PC 9, 13, 17. The Final Report of the Working Group on the Declaration is in UN Doc A/CONF 48/14/Rev 1/Annex II.

customary law. While recognizing both sovereignty and developmental concerns, it is clear that transboundary environmental harm must be controlled.[1]

> **The 1992 UN Conference on Environment and Development**

The International Union for Conservation of Nature began to promote sustainable use of resources. The turning point in UN policy was reached, when the World Commission on Environment and Development (WCED) published the "Brundtland Report", calling for a new approach, articulated as "sustainable development". The Brundtland Report suggested that the UN transforms its conclusions into a Program of Action on Sustainable Development, holds a conference to review implementation of this program, and institutes follow-up arrangements to "set benchmarks and maintain human progress within the guidance of human needs and natural law". The General Assembly decided to convene the UN Conference on Environment and Development (UNCED) for 1992, and it established a Preparatory Commission in which most of the negotiations took place[2].

Political objections from developing countries ensured that intergovernmental negotiating committees established by the General Assembly were given responsibility for drafting conventions on climate change and biological diversity, rather than UNEP, the World Meteorological Organization (WMO) or the Food and Agriculture Organization (FAO). Moreover, developing countries worked hard to coordinate their negotiating position.

The most significant environmental challenge of present time is global climate change. In this context, the "framework treaty" has provided the key regulatory tool. The 1992 Framework Convention on Climate Change is not the first treaty to address atmospheric

[1] E.g. Pathak, in Brown Weiss, *Environmental Change and International Law* (Michigan: United nation University press, 1992) 300.310.
[2] Alexander, Gillespie, *International Environmental Law, Policy and Ethics*, (UK: Oxford University Press, 2014), 19.

pollution, however, it is closely approached with two earlier models: the 1979 Convention on Long-range Transboundary Air Pollution and the 1985 Convention for the Protection of the Ozone Layer.

The slow pace of international negotiations is required to ensure global participation. Fundamental questions of economic equity between developed and developing countries are raised by ozone depletion and climate change, both of which are substantially the result of policies pursued principally by the developed, industrialized countries. Yet, without constraints on the pursuit of comparable policies by the developing countries, no control strategy will be implemented effectively. Thus the Ozone and Climate Change Conventions represent attempts to balance the economic concerns of developing countries with controls sought by developed countries. These equitable considerations must also be added the competing claims of future generations to inter-generational equity.

➢ **The 1997 Kyoto Protocol**

The Kyoto Protocol's most notable achievements are the stimulation of an array of national policies, the creation of an international carbon market and the establishment of new institutional mechanisms. Currently, the protocol is constrained by the modest emission limits and will have a limited effect on atmospheric concentrations[1]. Many options are identified for achieving emission reductions both under and outside the Convention and its Kyoto Protocol, for example: revising the form and stringency of emission targets, expanding the scope of sectoral and sub-national agreements, developing and adopting common policies, enhancing international R&D technology programmes, implementing development-

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[1] International agreements (climate change agreements and other arrangements), United Nation Intergovernmental Panel on Climate Change, accessed May 26th , 2014, available from treaties: https://www.ipcc.ch/publications_and_data/ar4/wg3/en/tssts-ts-13-4-international-agreements.html

oriented actions, and expanding financing instruments. Integrating diverse elements such as international R&D cooperation and cap-and-trade programmes within an agreement is possible, but comparing the efforts made by different countries would be complex and resource-intensive.

The next table summarizes the overview of international environmental agreements and some of its important treaties and conventions in this field.

Table (1.4): Major Environmental Treaties and Instruments

Year	Environmental Treaties
1909	Treaty between the United States and Great Britain Respecting Boundary Waters Between the United States and Canada (Washington). In force 5 May 1910.
1940	Convention on Nature Protection and Wild-Life Preservation in the Western Hemisphere (Washington). In force 1 May 1942.
1944	United States–Mexico Treaty Relating to the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande. In force 8 November 1945.
1945	Charter of the United Nations (San Francisco). In force 24 October 1945.
1946	International Convention for the Regulation of Whaling (Washington). In force 10 November 1948. Amended 1956. In force 4 May 1959.
1948	Convention on the International Maritime Organization (Geneva). In force 17 March 1958.
1950	International Convention for the Protection of Birds (Paris). In force 17 January 1963.
1954	International Convention for the Prevention of Pollution of the Sea by Oil (London). In force 26 July 1958. Amended 1962 and 1969.
1957	Interim Convention on Conservation of North Pacific Fur Seals (Washington). In force 14 October 1957.
1958	Convention on Fishing and Conservation of the Living Resources of the High Seas (Geneva). In force 20 March 1966.

1959	Antarctic Treaty (Washington) 402 UNTS 71; UKTS 97 (1961). In force 23 June 1961. 1991 Protocol
1964	Convention for the International Council for the Exploration of the Sea (Copenhagen).In force 22 July 1968.
1968	African Convention on the Conservation of Nature and Natural Resources (Algiers). In force 16 June 1969. Revised Convention of 2003 (q.v.).
1969	International Convention on Civil Liability for Oil Pollution Damage (Brussels). In force 19 June 1975.
1971	Convention on Wetlands of International Importance (Ramsar). In force 21 December 1975. Amended 1982 and 1987. In force 1 May 1994.
1972	Declaration of the United Nations Conference on the Human Environment (Stockholm) UN. In force 17 December 1975.
1973	Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington). In force 1 July 1975.
1974	Nordic Convention on the Protection of the Environment (Stockholm). In force 5 October 1976.
1976	Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona); Protocol Concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency; Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft. All in force 12 February 1978. 1980 and 1982 Protocols (q.v.). Revised convention and protocols 1995/6.
1978	Protocol Relating to the Convention for the Prevention of Pollution from Ships (MARPOL). In force 2 October 1983.
1979	Convention on the Conservation of Migratory Species of Wild Animals (Bonn). In force 1/11/1983. Convention on Long-Range Transboundary Air Pollution (Geneva) In force 16 Marci 1983.
1980	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based (Athens). In force 17 June 1983.
1982	Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (Jeddah) and Protocol Concerning Regional Co-operation in

	Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency. All in force 20 August 1985.
1985	Convention for the Protection of the Ozone Layer, (Vienna).In force 22 September 1988.
1987	Protocol on Substances that Deplete the Ozone Layer (Montreal). In force 1 January 1989.
1989	Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Basel). In force 24 May 1992.
1990	International Convention on Oil Pollution Preparedness, Response and Co-operation, (London). In force 13 May 1995. Amended 2000.
1992	Declaration of the UN Conference on Environment and Development, (New York). Framework Convention on Climate Change. In force 21 March 1994. Convention on Biological Diversity. In force 29 December 1993.
1995	UN Agreement Relating to the Conservation and Management of Straddling Fish Stocks and Migratory Fish Stocks, In force 11 November 2001.
1996	Protocol to the London Dumping Convention. In force 24 March 2006. Amended 2006.
1997	The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh, Morocco, in 2001, and are referred to as the "Marrakesh Accords." Its first commitment period started in 2008 and ended in 2012.
2000	Protocol on Biosafety (Cartagena). In force 11 September 2003.
2003	UNECE Protocol on Strategic Environmental Assessment. Not in force.
2004	UNECE Protocol on Civil Liability and Compensation for Damage Caused by the Transboundary Effects of Industrial Accidents on Transboundary Waters (Kiev). Not in force.
2008	Protocol on Integrated Coastal Zone Management in the Mediterranean. Not in force.

Source: Patricia Birnie, Alan Boyle, Catherine Redgwell, *International Law and Environment* (New York: Oxford University Press, 2009), xxvii-xxxvi.

1.3.3.   Ratification of Major Multilateral Environmental Agreements

Over the years, many MEAs have been negotiated and agreed at the international and regional levels. Some have a few parties and some have almost global participation. It has been believed that environmental agreements can be divided into two inter-related and overlapping generations: a first generation, of single-issue, use-oriented, and mainly sectoral agreements, while a second generation, takes a more holistic approach and focuses on sustainable development and sustainable use of natural resources[1].
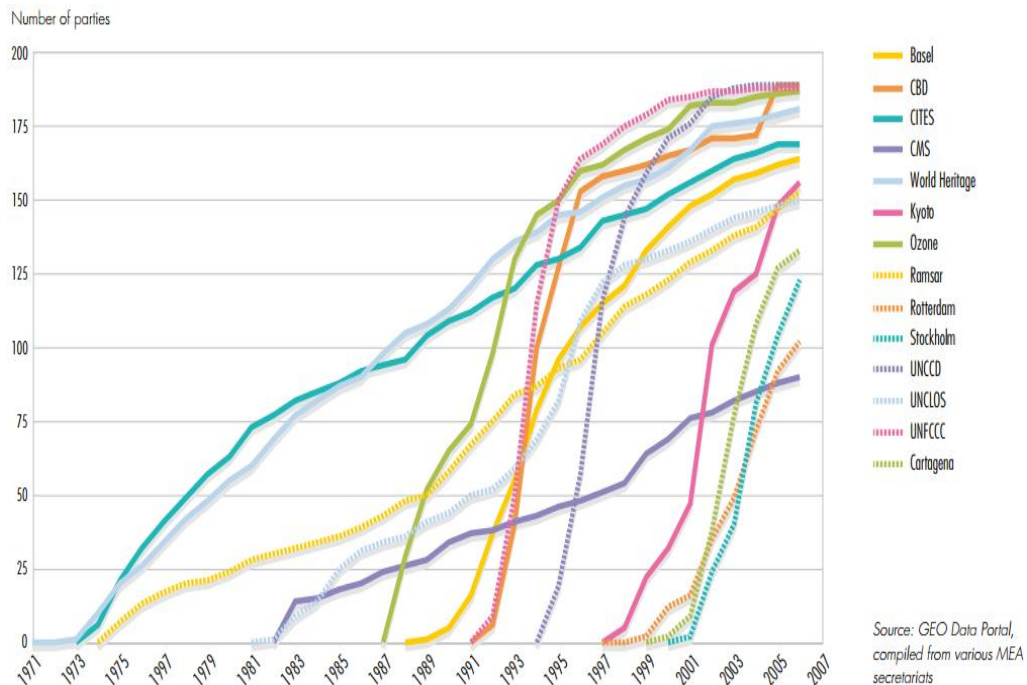
Figure (1.15): Ratification of Main Multilateral Environmental Agreements

Source: United   Nations   Environment   Program, http://www.unep.org/delc/Portals/119/audingmeas.pdf

First generation agreements primarily address the preservation and use of particular natural resources, such as wildlife, air and the marine environment. The examples

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[1] United Nations Environment Programe, *An Overview of Our Changing Environment*. (UNEP). 2008,   accessed May 28th , 2014, http://www.unep.org/yearbook/2008/ s

include the 1971 Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention), the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (London Dumping Convention), and the 1973 International Convention for the prevention of pollution from ships (MARPOL). These MEAs aim at principles for dealing with threats to living natural resources, global common resources and the marine environment.

Many of the second generation of more "holistic" MEAs developed in the United Nations Conference on Environment and Development (UNCED). This Conference, known as the Earth Summit, was held in Rio De Janeiro in June 1992 with government representatives from approximately 180 countries. Two new conventions were opened for signature: the UN Framework Convention on Climate Change (UNFCCC), and the Convention on Biological Diversity (CBD). The UN Convention to Combat Desertification (UNCCD) was adopted after the conference and aimed to combat desertification and mitigate the effects of drought. These three conventions together are often referred to as the "Rio Conventions".

Chapter Conclusion

After demonstrating the most important concepts related to environment and environmental pollution and its shapes, it became clear that the environmental problems were not coincidental, rather, they were the inevitable result of the pressurizing human treatments exerted on the environment through the industrial production, irrational consumption patterns...etc. That caused environmental pollution to demonstrate a painful reality to the modern life.

Before this huge amount of unresolved environmental problems, the world has become obliged to face serious and complicated ecological problems, the most important of which is the problem of Global Warming and climatic change. The worst problem about the latter two environmental problems is that their results are global; it does not separate the developing countries from the developed ones, who were the principle responsible for them in the first place.

For this particular reason, we have in the last part discussed the environmental conventions that have tried to find solutions through obliging countries to respect the environmental criteria to reduce the harm and protect the environment as a common right for us and for future generations.

Chapter Two

Chapter Introduction

This chapter presents different concepts about the economic growth, economic development and the classical and modern theories that explain the economic growth. Then it shifted to discuss the environment in traditional and modern economic thought, to prove clearly the high importance of considering the environmental side in the development programs for the wellbeing of human beings. In addition to that this chapter contains the emergence of a new approach of development called the sustainable development. The theoretical analyses of the relationship between economic growth and environment have been established under the explanation of the Environmental Kuznets Curve Theory.

2.1. The Definition and Measurement of Economic Growth

This section will discuss the different definitions of economic growth and the economic measurement. It will go further to elucidate the manners of measuring the economic growth and its different types, in addition to its pillars.

2.1.1. Definition of Economic Growth and Economic Development

2.1.1.1. The Definition of Economic Growth

The "Economic Growth" is a term frequently used in the economic literature, but up to date, there is no consensus about it. Here, we will see some definitions for this term and for "Economic Development".

✓ **Definition 01:** The Economic Growth is simply defined as the increase in the output of economy over a period of time that usually takes one year[1].

✓ **Definition 02:** The economist S. Kuznets defined the economic growth in his book *The Economic Growth and Structure*, as a long-term rise in the capacity of supplying the increasingly diverse range of economic goods of the population. This growing capacity is based on advanced technology and institutional and ideological adjustments needed[2].

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[1] Edward Shapiro, *Macro Economic Analysis,* 3rd edition (Toledo: Harcourt Brace JOVANOVICH INC, 1997), 369.

[2] Assar Lindbeck, *Modern Economic Growth: Findings and Reflections Noble Lectures in Economic Sciences 1969-1980, Simon Kuznets speech* (Singapore: World Scientific Publishing, 1992) 87.

✓ **Definition 03:** The economist François Perroux defined economic growth as a sustained increase during one or more periods, with a size indicator "net total production in terms of real value."

From the different definitions presented above, we conclude the following definition; the economic growth can be defined as the increase of economy's capacity to produce goods and services using new technology. It is measured in nominal or real terms, compared between one period of time and another, accompanied by an increase the in per capita income.

There is a big confusion between the concept of growth and development, thus, it is important here to address the definition of it and the difference between the economic growth and economic development.

❖ **The Definition of Economic Development:**

In general terms, *development* is defined as "the act or process of growing or causing something to grow or become larger or more advanced"[1]. When referring to the socio-economic system, development "means improvement in the general situation of the system. Development is a multi-dimensional concept in its nature[2], it may occur due to some deliberate action carried out by single agents or by some authority preordered to achieve improvement, to favorable circumstances in both

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[1]   Merriam-Webster English Dictionary, s.v., "development", accessed Mai 14, 2015, https://www.merriam-webster.com/dictionary/development

[2] Lorenzo G. Bellù., " Development and Development Paradigms A (Reasoned) Review of Prevailing Visions", FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO), (2011):2,   accessed   Jun   3rd   2014, http://www.fao.org/docs/up/easypol/882/defining_development_paradigms_102en.pdf

Development policies and private investment, in all their forms, are examples of such actions".

Furthermore, development is defined as, "The sum of the policies taken by a particular community, or the continual changes that lead to increased rates of economic growth on the basis of self-strength of this society to ensure the continued growth and its balance to meet the needs of the members of society in order to achieve the greatest possible level of social justice. Thus, economic development can be considered as resulting from two processes, leading on the one hand to efficiency growth and on the other hand, to variety growth and qualitative change"[1].

From the above definitions, we conclude that *development* is a multi-dimensional concept and can be viewed as a holistic exercise. It includes social, political, intellectual and organizational aspects needed to corporate together in order to provide a decent life for all members of the society.

Economists distinguish between the concept of economic growth and economic development from different aspects. Where Schumpeter addressed the difference between the two concepts, in his view, economic development is perceived as a spontaneous and discontinues change within the existing steady state that affects the general equilibrium of the previous state. On the other hand, economic growth highlights a gradual change over a long period of time, due to a general increase in the population as well as in the

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[1]Pier Paolo Saviotti, Andreas Pykab, "Economic development, qualitative change and employment creation, Structural Change and Economic Dynamics", *ELSEVIER,* (2004): 266, accessed Jun 3rd 2014,   http://dimetic.dime-eu.org/dimetic_files/Lect%208%20to%20Pyka%20-%20Saviotti%26Pyka2.pdf

economic dynamics [1] . Therefore, he sees that the accumulated quantitative changes represented by the economic growth will lead to qualitative changes of long-term economic development, thus, he believes that both economic growth and economic development are automatic.

In general, the economic growth indicates the measurable core confined in the economic field, while the development includes the shifts that take place in the structure of the economic, social and political forces-position in addition to changes in different aspects of life. Thus, the concept of development is wider than growth and covers it.

It is worth mentioning that in recent decades, the global interest has been growing in different fields and issues related to the development like environmental conservation issue, freedoms and the quality of governance…etc., and it confirms that the people are the real wealth of any country. Hence, a new approach of development called by the "Human Development" appeared. In view of this methodology, the poverty is not related just to the income level but also to the poverty of human capabilities and skills. Consequently, human development revolves around the human as a mean and goal of development at the same time.

The United Nations Development Program (UNDP) has adopted the approach of 'human development' through a series of human development reports, which began to be issued since 1990. Through the following table (2.1), we present a comparison between the economic growth and economic development.

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[1]Lorenzo G. Bellù, " Development and Development Paradigms A (Reasoned) Review of Prevailing", 2.

Table (2-1): Economic Growth vs. Economic Development

	Economic Growth	**Economic Development**
Purpose	Designed to increase the output within an economy.	Designed to structural change within an economy.
Measurement	Quantitative indicators: growth rate of Gross Domestic Product (GDP), GDP per capita GDP pc, Gross National Product (GNP).	Qualitative indicators: Gini index, human development index, etc.
Distribution of income	Is not designed for real income distribution amongst the society.	Concerned with 'Equity' in the distribution of real income by increasing the average income level especially for the poor class.
Uses	Economic growth is concerned with the optimal use of the available resources from the developed countries.	Economic development is usually associated with the exploitation of unused resources from developing countries.
Income	Concerned with increasing income GDP and its components such as consumption, investment, saving…etc.	Concerned with sources of increasing income and diversification of income, for example: building programs for educating people to create skilled work force to improve the total income level.
Effect	The changes within the economy are Quantitative.	The changes within the economy are both quantitative and qualitative.

Source: Compiles by Researcher based on the literature in this field.

2.1.2. Measurement and Types of the Economic Growth

2.1.2.1. Measuring Economic Growth

Economic growth can be measured in nominal terms, which include inflation, or in real terms, which are adjusted for inflation for comparing one country's economic growth to another. GDP per capita should take into account of consideration the population differences between countries[1]. Changes in the real GDP are expressed in percentage terms, where the growth rate is simply the change in real output between two periods divided by total output in the base period

$$\textbf{GDP Growth rate = Change in real GDP / base period GDP = …\%} \qquad (2.1)$$

Gross Domestic Product (GDP): is the total value of all the goods and services produced within a country in one year.

Real GDP: is the inflation-adjusted value of GDP where the value of output is measured in constant price.

GDP per capita: is simply the total output (GDP) divided by the population.

$$\textbf{GDP per capita = GDP (output) / population} \qquad (2.2)$$

Growth in GDP per capita is attained only when the growth of output exceeds population growth[2].

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[1]   INVESTOPEDIA, s.v., "economic growth" , accessed Mai 20, 2015, http://www.investopedia.com/terms/e/economicgrowth.asp#ixzz2Apw5YCm1

[2] Bradly R Schillir, *The Economy Today*, 8th edition (Pennsylvania: Irwin McGraw-Hill, 2009), 338.

2.1.2.2. Types of Economic Growth

The economic growth can be classified into two types:

A • Extensive Growth: Means the increase in quantities of factors of production (cultivation of new lands, new plants…etc.). Extensive growth generates new jobs. Growth through increasing input in terms of labor and capital input cannot continue indefinitely otherwise, the economy will suffer the problem of the diminishing marginal returns.

B• Intensive Growth: Means the increase in productivity gains, by using the same level of production factors, where labor and capital work harder. These are the technological innovations required to improve long-term living standards. Growth is driven by enhanced productivity (higher output per unit of input) rather than augmented production factors' supplies. Then intensive growth can be grasped by three "Cs," but three different "Cs": connection, communication, and consciousness[1].

2.1.3. The Four Pillars of Economic Growth

Economists who have studied growth have found that, the engine of economic progress must be established on the same four pillars (Human Resources , Natural Resources, Capital Formation, Technological Change), no matter how rich or poor the country is . They often write the relationship in terms of an *aggregate production function* or (APF), which relate total national output to inputs and technology .Algebraically, the APF is

$$Q = AF \, (\text{K}, L, R) \qquad\qquad (2.3)$$

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[1] Ervin Laszlo, *World Shift 2012, Making Green Business, New Politics and Higher Consciousness Work Together* (Toronto: Inner Traditions, 2009), 88.

Q refers to output

K refers to productive service of capital

L refers to labor inputs

R refers to natural-resource inputs

A represents the level of technology in the economy

F is the production function

In the following lines, we will investigate how each of these factors contributes to growth[1]:

a) **Human Resources:** A country might buy fast computers, modern telecommunication devices, advanced production machinery. However, only by skilled and trained workers, could these capital goods be effectively used and maintained to raise productivity. Nations that invest in health, education and training of their people will have more valuable workforce. Human capital includes education, training, skills and healthcare of the workers, and the value that they bring to the country's economy. Many economists believe that the quality of labor inputs - the skills, knowledge, and discipline of the labor force **-** is the single most important element in economic growth.

b) **Natural Resources:** It means "the gifts of Allah" and the second classic factor of production. Countries that have many natural resources are able to use them to produce goods & services cheaper than countries that have to import natural resources. If a country

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[1] William D. Nordhaus, *Economics,* 18th edition (Beijing: Posts and Telecom Press, 2011), 558.

has an abundance in natural resources, it can also trade them with other countries and make money for its economy.

c) **Capital Formation:** the tangible capital includes structures like roads, power plants, equipment like trucks, computers and stock of inventories. In the last century, waves of investments in automobiles, roads and power plants increased productivity and provided the infrastructure which created entire new industries. There is a strong relationship between the capital formation and the economic growth, where the countries that grow rapidly tend to invest heavily in new capital goods. Accumulating capital requires a sacrifice of current consumption over many years, which means saving today for a better tomorrow.   There are many investments, which can be undertaken only by the government and lay the framework for booming the private sector. These investments are called *social overhead capital* and consist of the large-scale projects that precede trade and commerce such as roads, irrigation, water projects and public health, so as the government must step in to ensure that these investments are effectively undertaken.

d) **Technological Change:** In addition to the three classic factors [1] discussed above, technological advance has been a vital fourth ingredient in the rapid growth of the living standards. Where, an endless stream of inventions and technological advances led to a vast improvement in the production. Technological changes denote changes in the processes of production or the introduction of new products or services. Process inventions that have greatly increased productivity were the steam engine, the generation of electricity, antibiotics…etc. Technological advance is in fact a continues process of small and large improvements. Because of its importance in rising living standards, the

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[1] Ibid.

countries encourage technological progress and try to offer the condition needed to develop it[1].

2.2.The Theoretical Fundaments of the Economic Growth

The following section will cover the various theories of economic growth, ranging from naturalism and mercantilism, the classical and neo-classical theories, in addition to other contemporary theories such as the Keynesian theory and other theories of those who came after Keynes.

2.2.1. Naturalism and Mercantilism Theories in the Economic Growth

2.2.1.1.Mercantilism in Economic Growth (17th Century- 18th Century)

The mercantilism called for the importance of achieving a powerful economic system for a country to serve its political purposes, and in order to achieve that economic strength, the country has to increase its resources from precious metals, such as gold and silver. Mercantilism considered trade as the major source to achieve those objectives and wealth. It distinguished between the social classes regarding their progress. According to them, progress should be only for the merchants, the manufacturers and the rich landowners. However, for the rest of the society members should not be benefited from that progress[2]. The mercantilism went even further than that and called for the decrease of the working class wages, because that will push this class to work more hours in order to improve their wages and this will lead to an increase in the total input. In short, the analysis of mercantilism to the local economic growth and the society's international exchanges can be described as M.

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[1] Ibid., 559.
[2] Lars Magnusson, *The Political Economy of Mercantilism*, 1st edition (New York: Tylor & Francis Group, 2015), 209.

Blaug puts it that, "the precious metals (gold and silver) are the basis of wealth, and the foreign trade is the source of this wealth"[1]. Therefore, it should be taken good care of through (1) encouraging industry by importing cheap raw materials and imposing taxes on such industrial products' imports, especially luxurious goods, (2) encouraging exportation, especially final goods' exports, (3) focusing on increasing the population with decreasing wages, because that will raise the total output. All this was to achieve a surplus trade balance in order to reach the prosperity of society." This prosperity, according to the mercantilism, is for the strength of the nation and not for achieving better living standards for the nation's members. Mercantilism interest concerning the economic growth was in the total income rather than the per capita income. Thus the size of the total output of any society gives a proof about its political strength.

2.1.1.2.Naturalism in Economic Growth (1st Mid of the 18th Century)

François Quesnay was the founding father of the Naturalist school. Quesnay drew the map of economics calling it the "Economic Table[2]" and this table is in itself a testimony of the depth of Quesnay's sight, in which his ideas have continued to exist almost until the mid of the 20th century, when Professor A. Philips came and translated the input data to input and output matrices (Input- Output). Therefore, he added some basics regarding the modern economic analysis to Quesnay's economic table. Quesnay says in his analysis that wealth

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[1] Erhun Kula., *History of Environmental Economic Thought*, 1st edition, (London: Routeldge, 2013), 14.
[2] David MckNally, *Political Economy and the Rise of capitalism A Reinterpretation* (California: University of California Press, 1990), 113.

arises from the agricultural production and flows into individuals from one hand to another, in order to fill the social body, the same as when it happens in the blood circulatory system.

Naturalist's center of attention was about the agricultural sector. It was considered as the only product[1]. They thought that the class of farmers has an extreme importance in the well-being of the community since it produces an excess production that can also be used in the development of the society. However, regarding the two other social classes, which are the landowners and the artisans, they were considered as non- producers and they tended to be highly consumers. Thus, the GDP's increase would stop on the amount achieved by the agricultural sector from the surplus and what is reinvested of this surplus in this sector. Yet, this depends on the distribution policy of the community's national income for the benefit of the consumer classes (artisans and landowners), the fact which would lead to the decline of GDP in the following period of time.

According to what was mentioned before, we can say that the Naturalists' vision concerning the economic growth focused on the importance of capital accumulation, and that the agricultural sector is the only sector responsible for the production, the fact which provides a surplus that creates capital accumulation. Moreover, it sheds light on the importance of individual initiatives, which can be achieved under the economic freedom, by demanding the natural rights, such as the right to own private property, the right to be guaranteed, the freedom to buy, sell, produce, import, export and the freedom of entry and exit of productive activity. Also, they gave great attention to the growth of individual production, in addition to their interest in the total output size.

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[1] Ibid, 106.

2.2.2   The Classical and Neo-classical Theories in the Economic Growth

2.2.2.1 The Classical Theory in the Economic Growth

By the end of 18th century and early 19th century, the west European countries witnessed the rise of the industrial revolution. Classical economists lived that period to build on it the basics of their ideas and opinions regarding the economic growth, its causes and how to achieve it. The most important ideas were in the writings of Adam Smith, David Ricardo and Thomas Robert Malthus, which we will discuss as follows:

  ➢ **Adam Smith's Analysis**

Adam Smith believes that the economic system is a natural system which is capable of making an automatic balance. Thus, economics should be free. Therefore, the government should not interfere in any economic activity, because it will prevent the growth of the national economy. He sees that the natural laws are responsible for organizing the continuity of the economic life through the concept of the "invisible hand". He also called for specialization of labor[1].

Adam Smith made a remarkable contribution in the analysis of the economic growth through his exposition of the general principles, which control the creation of wealth and income in his famous book *The Wealth of Nations*, which was published as a bestseller in 1772, and was further translated into several languages. Smith explains that the specialization and the division of work can ensure the increase of production and productivity, which lead to the increase of income and saving. The fact that capital accumulation essentially comes

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[1] Ibid, 153.

from saving, which represents the cornerstone in Smith's theory concerning the economic growth. Saving will be the basis for any economic growth, Smith says, and with the existence of the capital accumulation, the growth process becomes a renewed process by itself, in which the division of work raises the level of productivity leading to the increase of incomes and profits. Thus, additional parts will be added later for savings and investment (Larger capital accumulation). The specialization of work along with modern technology will lead to more production and more profits. Yet, at the same time it indicates that this process of growth has its limits, thus when the economy reaches the phase of capital accumulation intensity (investors will invest irrationally on certain domains), that will lead to the decrease in profits, saving and capital creation, until it ends with recession, which is considered as a phase of economic paralysis. The society will then reset the process of a forward accumulation all over again.

> **David Ricardo's Analysis**

Ricardo's ideas regarding the economic growth of the society can be summarized in the following points:

o Both Smith and Ricardo agreed that the total output depends on the factors of production: labor, capital, natural resources and the technical progress. He considered the natural resources (land) as a constant factor.

o Ricardo cared about the industrial sector[1], which, being the main source for the profits of the capitalist class is considered as the most effective sector in the growth of the

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[1]Ibid, 266.

community. In addition, he adds that the possibility of applying the modern techniques of productivity in this sector rather than the agricultural sector is important, the fact which would delay the appearance of revenues and create what is known as the diminishing returns law.

o Ricardo divided society into classes: the capitalist class which is responsible for the production, and two other classes which are the owners and the workers who spend their incomes on consumption.

o Ricardo agrees with Smith on the fact that creating a capital is the most essential part to any economic growth, and it is created by the capitalist class as result of its profits.

o Ricardo gave the population growth a major role in his model and showed that each addition to the population means that there is an additional mouth that eats and only two working hands. However, and with the overpopulation growth and those old mouths, those additional hands would be pointless and less productive, and will not add anything to the society; it will only lead to the decrease of production more and more, i.e.: decreasing revenues as a result of population congestion on the land, leading the community to resort to lower quality land.

o Ricardo's views of the capital is as a key factor for increasing the productivity of workers on one ground, yet with the passing of time and with the increase of applying capital on the same land, the decreasing of revenues will affect the capital as well.

o Ricardo called for the freedom of foreign trade which permits specialization or work division[1]. Thus, it can increase the total outcome especially the industrial production leading to the economic growth.

o Ricardo believes that the race between the population and the technical progress will be ultimately for the benefit of population growth, leading to recession.

   ➢ **Malthus' Analysis**

Malthus' ideas and proposals focused on two sides which are his theory concerning the people and his insistence on the importance of affective demand regarding development[2]. He is considered as the only classical economist who emphasizes on the importance of demand in determining the volume of production, and agrees with others on the supply side based on (Say) law, which says that supply creates demand.

o Malthus believes that the effective demand should grow as a proportion of the production possibilities in order to maintain the level of profitability, but there is no guarantee for that.

o Malthus focused on the savings of landowners and the imbalance between savings and the planned investments of the capitalists, which could reduce demand for commodities. In addition, he sees that any decrease in the consumption size will affect the development negatively.

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[1] William A.Kerr, James D. Gaisford, *Handbook on International Trade Policy* (UK: Edward Elgar Publishing Limited, 2007), 23.
[2] Ricardo Duchesne, *The Uniqueness of Western Civilization* (Netherlands: Hotei Publishing, 2011), 109.

As we have stated, the Malthusian theory of population has taken control of his analysis and his ideas concerning the economic growth in the society. He noticed that economic growth would not last long because the demand for labors depends, as in the thought of Smith and Ricardo, on the rate of capital accumulation. As a result, of the increase in population in comparison with the economic resources that are available in the society, the yields decrease (Law of Diminishing Returns), thus, affect the technical progress and from there the society would end up with recession.

In general, we can say that the classical economists have focused on the reasons of long-term growth in national income and the factors that lead to the achievement of growth. Among their greatest ideas in the field of economic growth are:

o   The freedom of foreign trade between the countries because it will increase the market capacity which would lead to the successful implementation of specialization and division of work.

o   The government should stay away from the economic activity except for a tight interval such as correcting the growth path of individual initiatives and reducing the population growth in particular.

o   The Economic growth depends on natural resources, labor, and capital and technological progress.

o   The capital accumulation is considered as the primary engine of growth because it is responsible for achieving technical progress and the possibility of applying the specialization and work division.

o   Applying specialization and work division will increase work productivity. Yet, it is limited in comparison with the market capacity.

Classical economists stated that economic recession has two reasons:

▪   The pressure resulted from population growth on the limited land space, leading to the rise of decrease in yields.

▪   Technical progress rate: If the race between population growth and technical progress is initially in favor of the technical progress, it would postpone or delay the entry into force of diminishing returns, but, on the other hand, if the large increase in the population surpasses the technical progress, it would eventually lead the community to recession.

2.2.2.2. The Neo-Classical Theory in the Economic Growth (Exogenous Growth Theory)

Classical economists argued that the size of the population, the amount of capital and technical level of productive affect the economic growth. They stated that the economic growth is determined by external forces, as they focused on short-term problems. In addition, they saw development as a continuous, progressive, harmonious and cumulative process.

Neo-classical economists, on the other hand, showed that the technological progress increases the capital formation process, which stands out as one of the most important things that the updated classical theory has come up with, in terms of its relationship with economic growth and with the assumption of the possibility of substitution between capital and work.

This means the possibility of accumulating capital without the need to increase employment, thereby, the creation of capital became liberated from the theory of population.

Solow Swan is considered as one of the leading pioneers of this theory. He stated that any increase in the GDP is due to a set of factors known as "Solow Residual[1]," and this is performed according to a particular equation.

He intended to break down the growth of output into the growth of the factors of production (labor and capital) and the efficiency growth in the utilization of these factors. The measure of this efficiency is generally referred to as Total Factor Productivity (TFP). For policy purposes, it may matter whether output growth stems from factors of production accumulation or from increases in Total Factor Productivity.

Solow founded the grounds for growth accounting. He considered one of the neoclassical functions of production as follows:

$$F(K_t, L_t) = K_t^{\alpha} L_t^{1-\alpha} \qquad (2.4)$$

Where:

Y_t Represents aggregate output

K_t Represents the stock of physical capital

L_t Represents the labor force

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[1] Peter Diamond, Growth/ *Productivity/ Unemployment* (London: MIT Press, 1993), 72.

A_t Represents Total Factor Productivity (TFP)

These factors appear in a neutral way. After some simple transformations, this equation can be written in terms of the growth rates of these variables. For more simplicity, consider the following Cobb-Douglas production function[1]:

$$F(K_t, L_t) = K_t^{\alpha} L_t^{1-\alpha} \qquad \text{With} \ \ 0 < \alpha < 1 \qquad (2.5)$$

Then, taking natural logarithms and differentiating both sides of (2.5) with respect to time t the growth rate of aggregate output can be expressed as

$$\dot{Y}/Y = \dot{A}/A + \alpha(\dot{K}/K) + (1-\alpha)(\dot{L}/L) \qquad (2.6)$$

(For a variable, $E = Y, A, K, L$ the term $\dot{E}$ stands for the derivative of E with respect to time t, and so $\dot{E}/E$ stands for the growth rate). Note that the growth rates of physical capital and labor are weighted by α and $(1-\alpha)$. As is well known, these weights correspond to the respective shares of rental payments for labor and capital in total income. With available data on α and the growth rates for output, labor and physical capital, TFP growth can be computed from (2.6) as the residual. Accordingly, TFP growth is the so called Solow residual. In addition to that, Solow sees that the technology progress is the main factor which determines the long- term economic growth. Solow found that the technological progress of the US was behind its economic growth in the first half of the 21st century[2].

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[1]Aloysius Ajab Amin., *Developing a Sustainable Economy in Cameroon* (Senegal: Council for Development of Social Research in Africa, 2008), 112.

[2] Dani Rodrick, M.R. Rosenzweig, *Handbook of Development Economics,* Volume 5 (UK: Elsevier, 2009), 4437.

The justification was that the return on capital decreases due to the increased capital
stock relative to output, until reaching the level of equilibrium, where it cannot increase the
capital ratio to production after that. Solow stated that investment and employment cannot
influence the long-term growth. On the other hand, we notice that the pioneers of this theory
considered the economic policy and the institutional system as neutral factors for long-term
economic growth. The theory also assumes that the relationship between per capita income
and economic growth rate is contradictory. The more per capita's average income increases,
the less its possibility for achieving high growth rates is. He explained that the countries with
low per capita income have a weak capital accumulation, and, thus, will achieve high
investment returns because of the availability of investment opportunities. This can lead to
conclude that the poor countries are capable of income convergence with the developed
countries if they succeed in increasing domestic and foreign investment.

2.2.3. The Growth Theory of Keynes and Those After Him

2.2.3.1.The Growth Theory of Keynes

The capitalist world of economy witnessed the Great Depression (1929-1933) where
unemployment spread over all aspects of the economy and poverty problem increased
widely, and that is why the issue of economic growth became once again important,
especially after the emergence of the Keynesian Revolution in the theory of income. Keynes
criticized the classical theory and Say law[1]. He stressed that the equilibrium level can happen
at any level of use and income, and not necessarily at the level of optimal resource utilization.
It should be noted that the level of utilization determined by aggregate demand, and that the

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[1] Allan H. Meltzer, *Keynes's Monetary Theory: A Different Interpretation*, (UK: Cambridge
University Press, 2005), 135.

problems experienced by the capitalist system do not lie in the supply of goods and services, instead, they lie on the side of effective demand. Keynes considered that ineffective demand is the essence of capitalism problem and investment is the function in the interest rate while savings are the function in income. Keynes emphasized that the production function depends on labor (on the grounds that, the economy has potential productivity possibilities untapped). Keynes has focused his attention on the economic stability more than on its growth, and his model deals with the determination of income level in a very short term. Under the Keynesian analysis, the balance of income and production (in closed economy) occurs when the planned investment equates with planned savings.

2.2.3.2.The Growth Theories After Keynes

➤ **Harrod Domar's Model**

The Harrod Domar Model in growth is considered as one of the easiest, most common and broader models. It was developed in the forties, and was linked to the British and the American economists Roy Harrod and Evsey Domar[1]. Both economists had built that model based on the ideas and the tools that Keynes brought. The model considers savings and investment as the basis of the economic growth.

The model assumes a relationship link between capital stock (K) and output (Y). This relationship is known in the economic literature as Capital- Output Ratio, which means that production is a function of capital stock. The Harrod-Domar model is based on the following assumptions:

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[1] G S Gupta, *Macroeconomics: Theory and Applications*, 2nd edition (New Delhi: Tata McGraw-Hill Publishing Company Limited, 2006), 370.

1- S= s. Y … (2.7)   The Saving represents a certain percentage from output.

2- I= Δ K… (2.8)   Investment represents change in capital stock.

Capital is related to output and therefore:

$Y = f(K)$ … (2.9)

$K = k.\, Y \Rightarrow \Delta K = k \cdot \Delta Y$ … (2.10)

3- S= I … (2.10) In case of equilibrium the saving is equal to investment.

From the equations (2.7), (2.8), (2.9), (2.10) it is clear that:

$I = \Delta K = k \cdot \Delta Y$ … (2.11)

$s \cdot Y = k \cdot \Delta Y$ … 2.12)

We divide both sides of the equation by k Y, and we get:

$$\frac{\Delta Y}{Y} = g = \frac{s}{k} \; … (2.13)$$

It is clear that **g** represents the output growth rate, which has a positive relationship with saving and negative relationship with capital ratio.

Where:

Y Represents output which is equal to income

K Represents capital stock

S Represents total savings

I stands for investments

K: Marginal Capital-output ratio which reflects the effect of additional units of capital on the output $k= \Delta K/ \Delta Y$.

s=saving rate s=S/Y

The Harrod-Domar model stated that the economic growth requires an increase in savings[1] and therefore, investment increases pushing the economic growth positively. This is the basic relationship in Harrod- Domar model, which supports the idea that the capital, which was created through investing in factories, in addition to the saving of individuals and companies, will led to economic growth.

The Capital-Output ratio shows simply the productivity of investment or capital.

➢ **The Endogenous Growth Theory**

The weak performance of the modern classical theories in explaining the long term Growth resources had its role in the emergence of new other theories regarding Growth (The modern theory of growth, endogenous growth…etc.), in which Paul Romer was the pioneer. The theory assumes that the growth continuity is determined by the its same production process rather than from outside factors, and the most important motive of this theory is the lack of answers from neoclassical theory to the question: why are there differences in economic growth rates between countries that have the same technical level? In addition to the motif of discovering the sources of the Solow residual.

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[1] Ibid., 376.

The theory assumes that the enhancement of human capital will lead to economic growth in any nation by means of the development of new forms of technology and effective and efficient means of production[1].

The theory notes that the increase in the returns on the marginal scale in production factors, through the role of the external effects in investing in human capital, will contribute in improving productivity and the tendency of the decrease of benefits. According to Lucas[2], the economic growth is based on savings and investment in human capital. On the other hand, according to Romer it is based on research, development and production of knowledge. Those economists stated that the variation in investment returns rates is attributed to the variation in investment in human capital (such as education, training, research and development), in addition to the availability of the infrastructure in the national economy. The economists of this theory also focused on the role of the public sector in achieving development goals (by improving the efficiency of resource allocation by investing in human capital and encouraging private investment in high-tech industries).

2.3. Analysis of the Relationship between Economic Growth and Environment

2.3.1. Environment in Traditional Economic Growth Thought

Since the rise of economics as a science, its primary interest was and still is to study, evaluate and try to resolve the problem of the relative scarcity of resources. Economics is interested basically in the process of allocating scarce resources to satisfy the humanitarian

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[1]   INVESTOPEDIA, s.v., "new growth theory" , accessed Mai 23, 2015, http://www.investopedia.com/terms/n/new-growth-theory.asp#ixzz4Y5FcZt3w
[2] Flavio Romano, *Clinton and Blair: The Political Economy of the Third Way*, (Canada: Routledge, 2006), 31.

needs by trying to achieve full and optimal employment of resources. Therefore, many economists recognized environmental pressures and what they represent as an important constraint on growth, thus, this is not a new issue; instead, it is as old as economics itself. In the next lines, we review briefly the views of each of Malthus, Ricardo, and Mill.

2.3.1.1.Robert Malthus' Analysis (1766-1834)

Over long periods of human history, the economic activity depended on land as the main supplier for the production process, farming, grazing and mining. The idea of environmental resources depletion was prevalent for a long period of time. The article of Malthus presented in 1978 entitled [1] "An assay on the Principle of Population as it Affects the Future Improvement of Society," was one of the first works that dealt with the concept of scarcity from an economic perspective. In this article, Malthus alerted to the seriousness of excess consumption of the limited resources of food and the need to take into account the limits of the physical environmental resources that ecologists talk about today.

Malthus in his article had presented the relationship between the expansion of population growth and the cultivation of new lands. With the abundance of agricultural land in the beginning, farmers were turning to the use of fertile lands in the cultivation and production of food commodities in order to provide the population needs[2]. However, with the continuous increase of population, their needs increase as well, pushing the production of food and commodities to increase towards meeting these needs by exploiting new lands

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[1]Thomas Malthus, "An Essay on the Principle of Population", *Electronic Scholarly Publishing Project*, (1978):6, accessed Jun 10th , 2014, http://www.esp.org/books/malthus/population/malthus.pdf
[2] Ibid., 7.

until they become exhausted. That calls the farmers to intensify labor on agricultural lands to face the growing necessities of the population leading *Diminishing Returns Law* to appear.
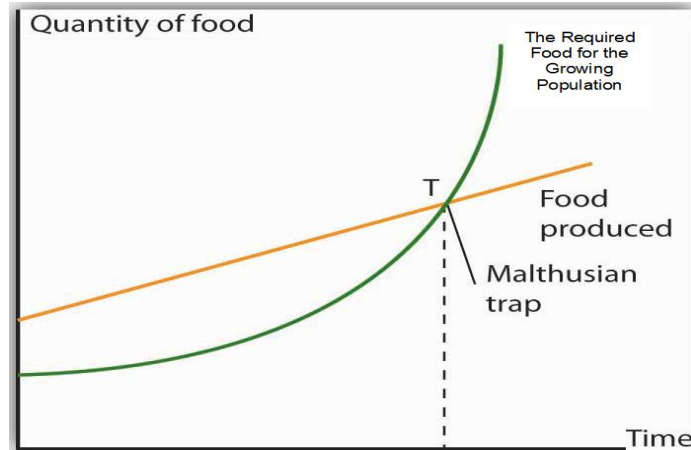
Figure (2.1): Population Growth and economic Development

Source: Population Growth and Economic Development, accessed Jun 10th, 2014

http://www.web-books.com/eLibrary/ON/B0/B62/095MB62.html

Based on this, Malthus has launched his pessimistic call in an article about population. This Malthusian pessimistic call still reverberates in the conferences and seminars' halls that are concerned with the environment and population. The main idea cited by Malthus in his theory is that there are two opposing forces, which are population and the ability of land to produce enough food. If the population has the ability to grow at rapid rates while resources cannot, they will suffer depletion. If the governments do not curb the population growth in optional ways (birth control), the resources depletion and the slow growth of these resources,

especially food (fixed quantities of agricultural lands) will end by famine, diseases and wars a process that is called the Malthusian Crisis[1].

From here, the awareness about the environmental problem by economists is not new. This Malthusian opinion is one of the important contemporary concerns about the viability of the environment in its support for the unremitting economic growth. It is worth mentioning that, the main problem that the Malthusian analysis suffers from, is neglecting the power of technological development in general and particularly in the agricultural field.

2.3.1.2.David Ricardo's Analysis (1772-1823)

As for Ricardo, who is one of the pioneers of the classical school in economics, he saw that the vast economic growth that accompanied the industrial revolution in England and Europe would inevitably collide with the limitations imposed by the scarcity of fertile agricultural lands. His theory was adopted on the idea of scarcity and limited resources. Ricardo did not wander with the total space of earth as Malthus did. Instead, he put a distinction between different types of land according to the degree of quality or fertility. According to him[2], the increase in population will lead to exploit fertile agricultural lands first, and with the continuation of overpopulation, people would move to exploit less fertile lands. Thus, expanding the demand for food with each wave of investments always leads to the introduction of (less fertile lands) low-productivity, in which the marginal cost of

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[1] Ibid., 8.
[2] Rhona C. Free, "21st Century Economics: A Reference Handbook", Volume 1, Sage Publication Ltd, UK, 2010, p. 05.

production of agricultural commodities increases more and more (see the prices in the following figure).
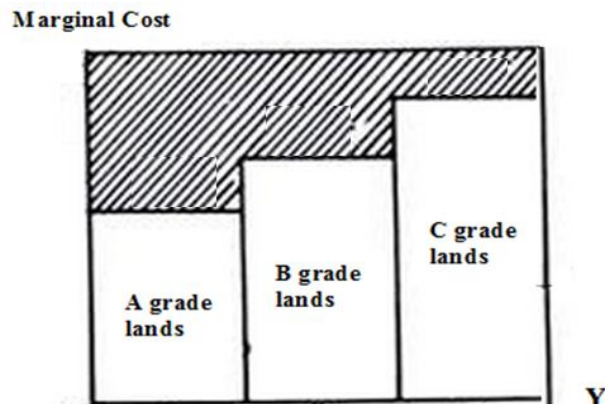
Figure (2-2): Ricardian Model of Rent (Grades of lands)

Source: Economics Discussion, http://www.economicsdiscussion.net/theory-of-rent/ricardian-theory-of-rent-with-diagram/1799

Thus, the fertile land rent increases and workers will ask for raising their wages to maintain a subsistence level, where industrialists respond to this by decreasing profits. The result is that with every decrease in profits, there will be a decrease in motive to launch a new investment wave, and this slows the rate of investment and growth, therefore, the economy would suffer diminishing returns and eventually reach a steady state.

This means that, each of the analysis of Malthus and Ricardo ends up with one result, which is the expansion in the exploitation of resources, the diminishing returns and the increase in the marginal cost due to the low quality of lands. This will ultimately lead to the inability of the economy to provide sufficient quantities of food to meet the population needs.

2.3.1.3.John Stuart Mill's Analysis (1806 - 1873)

John Stuart Mill accepted the analyses of Malthus and Ricardo including the idea of limited resources, however, he differed with them in the inevitable occurrence of a continuous increase in the population and the effects of such an increase. He noted in his *Principles of Political Economy* in 1848, that the continuous increase in the population is not inevitable. He furthermore pointed out that the growth in general, including economic growth, cannot be limitless; rather it would inevitably arrive at an equilibrium level. He believed that the economic growth that humanity has achieved during the eighteenth and nineteenth century, was the result of a race in order to achieve physical targets, and that will not be always the case. In his view, human well-being cannot be measured only including materialism sides. This means that economic growth, according to the opinion of Mill will not solve the problems of humankind and would not be in favor of the welfare of future generations[1].

In general, it can be said that John Stuart Mill was not pessimistic like his predecessors (Malthus and Ricardo), despite his belief in the applicability of diminishing returns in agricultural production. However, he saw the ability of scientific and technological progress to raise the efficient use of natural resources and postpone the entry into the law of diminishing returns.

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[1] Oskar Kurer, *John Stuart Mill: The Politics of Progress* (New York: Routledge, 2016), 79.

2.3.2.   Environment in Modern Economic Thought

The environment in the modern economic thought has shown interest in the traditional theory of the environment within the scope of interest in the allocation of natural resources, which is concerned with the optimum extraction of non-renewable resources, and thus it determines the growth rates of renewable resources. In addition, economic analysis remained interested in maximizing economic activities and improving their efficiency. By the end of the sixties and early seventies, some of the studies have shown interest in the scope of economic theory by showing that the economic system itself falls within the ecosystem emergence. They have called for a comprehensive restructuring of the economy so that it merges with the ecosystem. The most important of these studies was brought by the economic Kenneth Boulding who developed a paper in 1966 entitled "The Economics of the Coming Spaceship Earth". It explained that traditional economic analysis looked at the natural environment on the part where they provide input in the form of raw materials and outputs in the form of waste. It focused on the process, which was made between the parties.

2.3.2.1. Boulding Thought

Boulding criticized the approach that neglects the environment, and handles it only through the raw materials provided, which turn into waste without regard to the material used[1]. This material used by man today limits the extent that he looks forward to use tomorrow. Boulding thought that there are many materials available and that they are suitable for what he calls a look of a cowboy economy man, moving easily across pastures stretching

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[1] Matthias Beck, Beth Kewell, *Risk: A Study of Its Origins, History and Politics* (Singapore: world scientific publishing, 2014), 194.

without worries; and that the production of this cowboy and its consumption has a very little impact on the broad neglected environment. He furthermore states that the raw materials consumed today do not limit the amount which this cowboy man hopes to consume tomorrow vis à vie the availability of more resources.

Boulding states, "I am tempted to call the open economy the "cowboy economy," the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behavior… The closed economy of the future might similarly be called the "spaceman" economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything … and in which; therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy[1]."

Boulding calls the need to replace the cowboy economy with the spaceman economy, a man who goes on the back of a spaceship with limited inputs and a limited ability to carry waste. The space closed system in which the spaceman uses inputs within the range of his ability to continue to live on board the spaceship a life that is based on recycling wastes. This theory shows that, the environmental impacts of economic activity must take place within the limits of life reservation on the back of the spaceship. From here, considering the environment as a spaceship or as a closed system makes it one of the most important human goals during the long period; in which the maintenance of this ship is achieved through a the

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[1]Peter G. Brown, " An Economics For Spaceship Earth A time for witness—A time for service ", *QUAKER ECO-BULLETIN Information and Action Addressing Public Policy for an Ecologically Sustainable World*, Volume 4, Number 2, (March-April 2004), accessed Jun 11th , 2014 http://www.quakerearthcare.org/sites/quakerearthcare.org/files/qeb/qeb4-2-spaceshipearth.pdf

increase of the level of efficiency, the decrease of investment and consumption as much as possible[1].

This environmental ideology along with others have created a motive for economists to re-search actively in the main pillar of the economy, the scarcity of resources and their relationship to the potential use. It has, in addition, crystallized a number of opinions, the fact which resulted in the birth of a new branch of economics called "The Economics of the Environment" or "Environmental Economics".

- **Definition of Environmental Economics:** Environmental economics is an area of economics that studies the financial impact of environmental policies. Environment economists perform studies to determine the theoretical or empirical effects of environmental policies on the economy. This field of economics helps users design appropriate environmental policies and analyze the effects and merits of existing or proposed policies.

The basic argument underpinning environmental economics is that there are environmental costs of economic growth that go unaccounted in the current market model. These negative externalities, like pollution and other kinds of environmental degradation, could then result in market failure. Environmental economists thus analyze the costs and benefits of specific economic policies, which also involves running theoretical tests or studies on possible economic consequences of environmental degradation[2].

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[1] Matthias Beck, Beth Kewell, *Risk: A Study of Its Origins, History and Politics,* 195.
[2] INVESTOPEDIA, s.v., "environmental economics" , accessed Mai 24, 2015, http://www.investopedia.com/terms/e/environmental-economics.asp

2.3.2.2.The Limits to Growth

Before more than 30 years ago, a book called *The Limits to Growth* commissioned by the Club of Rome, created an international sensation. *The Limits to Growth* was compiled by a team of U.S. and several foreign countries' experts. Using system dynamics theory and a computer model called "World 3," the Club of Rome computer models suggested that continued economic growth will deplete resources and increase pollution until industrial output, food production and services decline causing catastrophic population loss during the twenty first century. Through presenting and analyzing 12 scenarios that showed different possible patterns and environmental outcomes of world development over two centuries from 1900 to 2100, the world 3 scenarios practically showed how population growth and natural resources' use interacted to impose limits to industrial growth, in a novel and even more controversial idea at the time. In 1972, however, the world's population and economy were still at ease within the planet's carrying capacity. The team found that still there was room to grow safely while we could examine longer-term options[1].

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[1] Donella Meadows, Jorgen Randers, and Dennis Meadows, " A synopsis limits to Growth: The 30-Year Update", accessed Jun 11th , 2014, http://donellameadows.org/archives/a-synopsis-limits-to-growth-the-30-year-update/
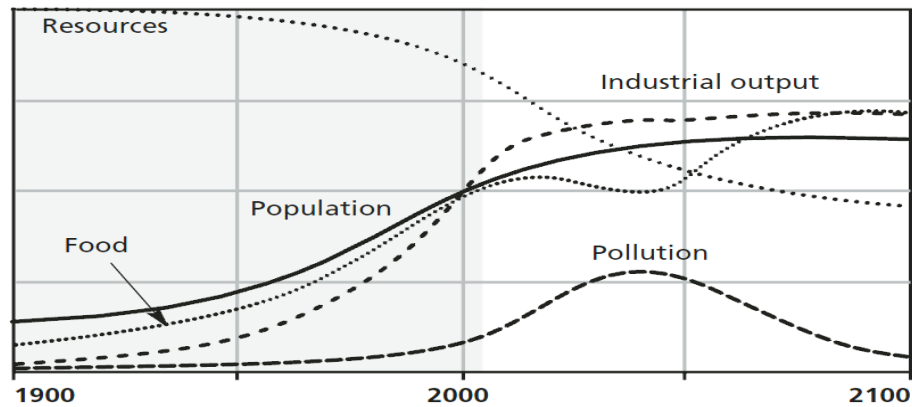
Figure (2.03): State of the World

Source: A   synopsis   limits   to   Growth: The   30-Year   Update,

http://donellameadows.org/archives/a-synopsis-limits-to-growth-the-30-year-update/

2.3.2.3.Sustainable Development

Sustainable development is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs[1]", in other words ensuring that today's growth does not jeopardize the growth possibilities of future generations. Sustainable development comprises three elements: economy, society and environment, which have to be considered in equal measure at the political level. It is the view that we must use to deal with the environment, society and the economy properly. The environmental sustainability implies not depleting renewable resources faster than their replacement.

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[1] Jeffrey Gold, Richard Thorpe, Alan Mumford, *Gower Handbook of Leadership and Management Development* (England: Gower Publishing Limited, 2010), 476.
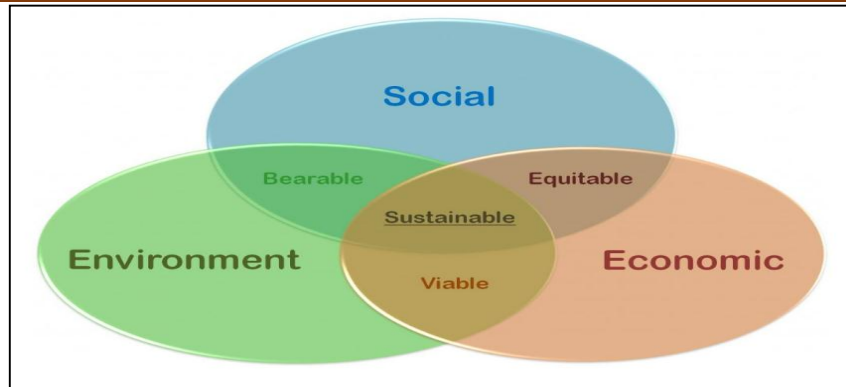
Figure (2.4): The Three Dimensions of Sustainable Development

Source: Earth System Governance, accessed Jun 12, 2014 http://sdg.earthsystemgovernance.org/sdg/publications/sdgs-beginners

Both efficiency and ethical consideration can guide the desirability of private and social choices involving the environment .Whereas the former is concerned mainly with eliminating waste in the use of resources, the latter is concerned with assuring the fair treatment of all parties. With regard to the goals, objectives and standards, these must be first defined and applied at the national or local level. Societies should decide what goals and objectives they want to satisfy, how and when. Some problems are global and/or regional, requiring International Corporation and the preparation and implementation of international treaties. In this case, objectives and goals are defined by the consensus, which means that indicators are factors that should jointly be defined and used for the different stages and levels of decision-making[1].

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[1] Manuel Winograd and Andrew Farrow, "DIMENSIONS OF SUSTAINABLE DEVELOPMENT, Sustainable Development Indicators for Decision Making: Concepts, Methods, Definition and Use", Vol. I, accessed in Mai 27 2015, http://www.eolss.net/SampleChapters/C13/E1-46B-02.pdf

The previous theories dealt with, both traditional and modern, could be summarized in the following three directions:

- **The first direction:** believes that environmental resources are limited, including energy, water, land, raw materials…etc… Furthermore, the ability to absorb the waste that economic growth would exhaust from the environment and its limited resources, would raise the issue of ensuring the endless continuity of economic growth at the expense of the environment. The renewable sources depend on energy such as solar power and thus, they even drag the rate of environmental resources with the capacity of these resources to regenerate.

- **The second direction:** it is more optimistic than the first direction. The supporters of this direction believe that, increasing the consumption of renewable environmental resources and non-renewable ones creates real incentives for human behavior that always moves towards rationalization. The investigation for alternatives and innovation productivity arts reduces the direct dependence on environmental resources and increases the recycling rate. Economic growth is always at risk of collision of scarce resources, and this is why, supporters of this direction push the market-mechanism in the direction of the optimal allocation of the available resources. However, this direction ignores an important fact, which is that most of the environmental resources have no markets in the strict sense. Therefore, the benefit from the oceans, rivers, lakes and forests cannot be market-style in an optimal manner.

- **The third direction**: The supporters of the third direction see that, if the mechanical market fails to allocate the environmental resources in a perfect allocation, governments can interfere with the various policies, such as taxes, subsidies, licenses, direct ban,

defining property-rights and judicial advanced systems, in order to enhance the market-mechanism concerning resource allocation. In addition, they need to reduce the environmental misuse in order to remain able to continue fulfilling human needs. However, the supporters of this view see that dumping the waste is the other thing that governments may fail to control, due to many reasons, where, governmental bodies and institutions could surpass this principle by the destruction of resources and abuse of the environment. As an example, there is the establishment of factories in the heart of densely populated capitals in the developing countries, or dumping sewage near the coasts or in lakes.

2.3.3. The Relationship between the Economic Growth and Environmental Degradation under EKC Hypotheses

2.3.3.1. The Origins of Environmental Kuznets Curve

This environmental pattern has been called Environmental Kuznets Curve (EKC) due to the similarity in the relationship between the level of inequality and per capita income considered by Kuznets (1955) [1] in his presidential address entitled by "Economic Growth and Income Inequality". He hypothesized an inverted -U- income – inequality relationship, whereby the inequality increases with the per capita income, until it reaches a certain point called the "income turning point", followed by the decrease in the inequality, whereas the per capita income keeps on increasing. A resemblance of this theory was noted by Grossman and Kruger through their empirical study. They tested the validity of the EKC hypothesis and

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[1] Kuznets Simon., "Economic Growth and Income Inequality", *American Economic Review*, Vol XLV, (1955): 27, accessed Mai 20, 2015, http://piketty.pse.ens.fr/files/Kuznets1955.pdf

found that there was an inverse-U-shaped relationship between economic growth and environmental degradation[1].

2.3.3.2.The Environmental Kuznets Curve Hypotheses

The EKC hypothesis assumes that there exists an inverse-U-Shaped relationship between economic activities (usually measured in terms of "per Capita Income", and the environmental quality) measured by environmental indicators such as per capita CO_2 emissions. That is to say, at the first stage of the economic growth, environmental degradation would increase with an increase in per capita income, but it would then begin to decrease as the rise in per capita income passes beyond the income turning point.
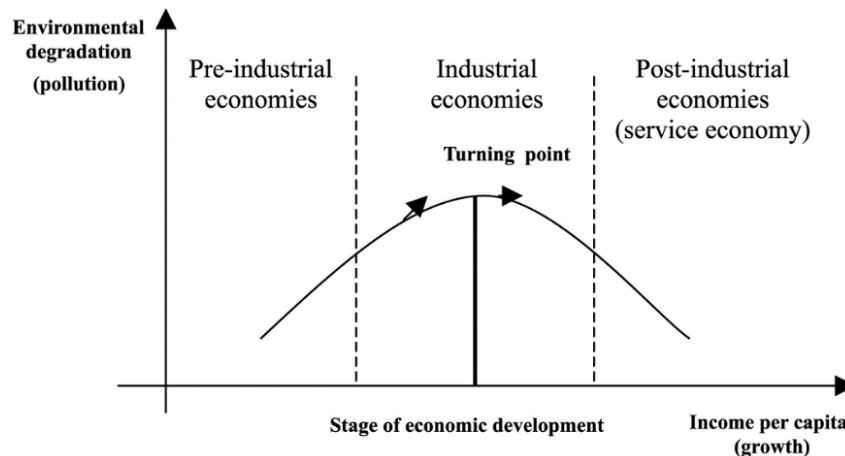
Figure (2.5): The Inverted U-shape of Environmental Kuznets curve

Source: Panayotou, T, "Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development", Working Paper WP238 Technology and Employment Programme, Geneva: International Labor Office,(1993): 19.

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[1] Grossman, G.M. and Krueger, A.B, " Environmental impacts of a North American Free Trade Agreement", *Quarterly Journal of economics*, Vol. 110, No. 2, MIT Press, (1995):372, accessed Jun 1st 2015, http://www.econ.ku.dk/nguyen/teaching/Grossman%20and%20Krueger%201995.pdf

The EKC hypothesis, thereof, illustrates that as a country develops its industry, the environmental degradation increases accordingly to it, and it would start decreasing after reaching a certain level of economic progress (Figure 2.5). Its implicitly suggests that environmental damage is unavoidable in the first phase of economic development. Panyotou[1] suggested several reasons for the inversion of pollution patterns. First, the turning point for pollution is the result of more affluent and progressive communities placing greater value on cleaner environment, and thus, putting into place institutional and non-institutional measures to affect this environment. Second, pollution increases, at the early phase of a country's industrialization, due to rudimentary, inefficient and pollution-generating industries appearing on the industrial area. When industrialization starts to achieve more advanced levels until it is sufficiently advanced, the pollution will stop increasing, rather, it will start to take a U-turn. Moreover, service industries will gain prominence causing a further reduction in pollution.

Furthermore, the polluted industries will shift from the developed countries to developing countries where the developing countries are in the early stages of economic development. Lucas et al. indicated that, the environmental regulations in developed countries might further encourage pollution generating activities to gravitate towards the developing countries[2]. For the sake of development, these countries sacrifice their

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[1] Panyotou, T., "Economic Growth and the environment", Spring Seminar of the United Nations Economic Commission for Europe, Geneva, (2003): 03.

[2] Lucas, R., Wheeler, D., Hettige, H, "Economic development, environmental regulation and the international migration of toxic industrial pollution: 1960–1988. In: Patrick, Low (Ed.)", *International trade and the environment, World Bank Discussion Paper*, vol. 159, Washington, DC, (1992):70.

environment accepting those industries offered by the developed countries. The result is a greater amount of pollution in the developing countries Dinda[1].

One of the best ways to explain the EKC is income elasticity of environmental quality demand. In the early stages of economic development, the people are more focused on and interested in eliminating poverty and improving their living conditions, while ignoring (willingly or unwillingly) the importance of environmental protection because of low-income elasticity of demand for the environmental quality. As their income grows, their living standards also increase. Then, they start caring about the quality of environment. Their desire and demand for a clean environment leads to structural changes in economy and environmental policies to reduce the environmental degradation. It is important to note is the point claimed by some researchers that the environment quality is a luxury good at the early stages of economic growth[2].

Other studies have found even significant cubic income-pollution relationship that takes the form of an N-shaped curve (Figure 2-6) with two turning points[3]. Which means, environmental degradation increases initially, declines after reaching the first point, and then increase indefinitely beyond the second turning point. Birgit Friedl et al [4] also found a cubic N-shaped relationship between GDP and CO_2 emissions.

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[1] Dinda, S, "Environmental Kuznets curve hypothesis: a survey". *Elsevier Ecological Economics*, Vol. 49 No. 4, (2004), 445, accessed Jun 5th , 2015, ftp://filer.soc.uoc.gr/students/aslanidis/My%20documents/papers/Dinda%20(2004).pdf
[2] Mcconnell, EK. «Income and demand for environmental quality». Environment and Development Economics, Volume 2, Issue 4, Cambridge University Press, July 1997, p. 389.
[3] Grossman, G.M. and Krueger, A.B, op. cit., p. 364.
[4] Birgit Friedl, Michael Getzner., "Determinants of CO2 emissions in a small open economy", *Ecological Economics,* (2003): 138, accessed Jun 10th , 2015,
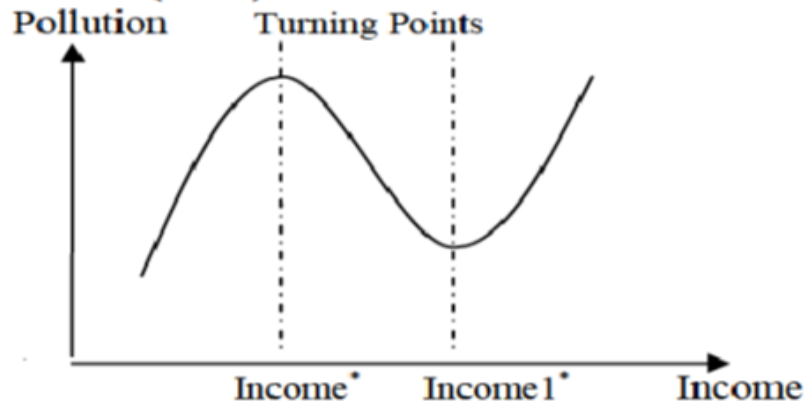
Figure (2.6): The N-shape of Environmental Kuznets Curve

Source: Ying Liu., "Trade, growth, and environment nexus: the experience of China, 1990-2007". Master of economics by Research thesis, school of economics, Faculty of commerce, University of Wollongong, 2009, 09.

2.3.3.3.Environmental Kuznets Curve Model

The earliest EKCs were simple quadratic functions of the levels of income. However, we will consider a parametric cubic model, which is a standard in the EKC literature, in order to investigate the various shapes and forms of EKC, which may exist between the economic growth and the environmental degradation. The standard EKC model takes the following form:

$$E_t = \alpha_0 + \alpha_{1t} + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \gamma x_t + \varepsilon_t \qquad (2.14)$$

Where:

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ftp://ftp.soc.uoc.gr/students/aslanidis/My%20documents/papers/Friedl%20&%20Gelzner%20(2003).pdf

E_t is the environmental indicator like per capita

CO_2 emissions

Y_t is per capita real GDP

X_t refers to vector variables that may affect E_t such as energy consumption, trade openness, population growth…etc.

εt is a random error term.

α_0, α_1 are intercept and trend parameters.

The model is usually estimated with panel data, but in the recent years, many studies took place, in different countries, to investigate the specific patterns in each country or group of countries using different econometric methods and tools in estimating the EKC.

Equation (2.14) allows testing various forms and shapes of environmental Kuznets curve. These include:

$\beta 1>0$, $\beta 2<0$ and $\beta 3>0$ indicates an N- shaped relationship

$\beta 1<0$, $\beta 2>0$ and $\beta 3<0$ indicates an inverse N-shaped relationship

$\beta 1<0$, $\beta 2>0$ and $\beta 3=0$ a U-shaped relationship

$\beta 1>0$, $\beta 2<0$ and $\beta 3=0$ reveals an inverse U-shaped relationship

$\beta 1>0$ and $\beta 2= \beta 3=0$ that indicates a monotonically increasing linear relationship

$\beta 1< 0$ $\beta 2= \beta 3=0$ reveals a monotonically decreasing linear relationship.

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The ''turning point'' level of income, where emissions or concentrations are at a maximum, can be found using the following formula:

$$\tau = [-\beta_1 / (2\beta_2)] \qquad\qquad (2.15)$$

Most parts of the research on EKC have been aimed to identify the income turning point, where this point varies from pollutant to pollutant. Neumayer cited a range of between $55,000 and $90,000[1] as the income turning point for CO_2, based on specific assumptions. while Grossman and Kruger[2] estimated the income turning point under $8000 for gas and Selden and Song's[3] estimated that the income turning point is under $10000. Because of the sensitivity of these results to the changes in the model, Stern[4] indicated that the conclusions drawn cannot be considered robust. In addition, he suggested that many of this econometric work is flawed in that it often fails to take into account of consideration problems such as heteroscedasticity, simultaneity, omitted variables or co-integration. Alternatively, it may simply be the case that there is no single relationship between emissions and income and that the evolution of emissions is dependent on many factors that vary and change according to circumstances.

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[1] Neumayer Eric, "National Carbon Dioxide Emissions: Geography Matters". Geography matters online, 2004, London, LSE research, accessed Jun 27th , 2015, http://eprints.lse.ac.uk/602/1/Article_for_Area_REVISED.pdf

[2] Grossman, G.M. and Krueger, A.B, " Environmental impacts of a North American Free Trade Agreement", 373.

[3] Selden, Thomas M. and Daqing Song, "Neoclassical Growth, the J Curve for Abatement, and the Inverted U Curve for Pollution", *Journal of Environmental Economics and Management*, Vol. 29, Issue 2, (1995),162-68, accessed Jun 17th , 2015, http://www.sciencedirect.com/science/article/pii/S0095069685710388?via%3Dihub

[4] Stern. David I, "The Environmental Kuznets Curve". *International Society for Ecological Economics Internet Encyclopedia of Ecological Economics, Department of Economics, Rensselaer Polytechnic Institute*, Troy, NY 12180,USA , (2003), accessed Jun 25th , 2015, http://isecoeco.org/pdf/stern.pdf

2.3.3.4.The Theoretical Criticism of Environmental Kuznets Curve

As all theories, the EKC theory has its share of criticism. This part discusses the theoretical criticisms under this theory. The key criticism of Arrow et. al.[1] was that the EKC model, as presented in the World Development Report and elsewhere, assumes that there is no feedback from environmental damage to economic production given that income is assumed to be an exogenous variable. The assumption is that environmental damage does not reduce economic activity sufficiently to stop the growth process and that any irreversibility is not severe enough to reduce the level of income in the future. Satisfying the material needs of people requires the use and disturbance of energy flows and materials. Therefore, an effort to reduce some environmental impacts might just aggravate other problems [2]. The estimation of EKCs for total energy use is an attempt to capture environmental impact regardless of its nature. It is clear that the levels of many pollutants per unit of output in specific processes have declined in developed countries over time with technological innovations and increasingly strict environmental regulations. However, the mix of waste has shifted from sulfur and nitrogen oxides to carbon dioxide and solid waste, so that aggregate waste is still high and per capita waste might not have declined. Economic activity is inevitably environmentally disruptive in some way.

EKC theory assumes that the economic growth in the early stages harms the environment but after a certain point (income turning point), the economic growth becomes a cure where it fixes and reduces the environmental damage despite the fact that economic

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[1] Arrow, K., et al, "Economic growth, carrying capacity, and the environment", *Policy forum, Science,*   Vol.   268,   (1995):   520-521. http://www.precaution.org/lib/06/econ_growth_and_carrying_capacity.pdf
[2] Stern. David I, "The Environmental Kuznets Curve".

growth continues in increasing. Some studies did not find empirical evidence to support the validation of EKC hypothesis such as De Bruyn et al [1] and V. Lantz, Q Feng[2], those studies found that CO_2 is unrelated to GDP. Other critics argued that if there was an EKC type relationship, it might be partly or largely a result of the effects of trade on the distribution of polluting industries. The Hecksher–Ohlin trade theory, suggests that, under free trade, developing countries would specialize in the production of goods that are intensive in the production inputs they are endowed with, in relative abundance to labor and natural resources.

The developed countries would specialize in human capital and manufactured capital-intensive activities. Part of the reductions in environmental degradation levels in developed countries and part of the increases in environmental degradation levels in middle-income countries may reflect this specialization. Lucas et al stated in his research that he strict environmental regulations in developed countries might further encourage polluting activities to gravitate towards developing countries[3].

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[1] De Bruyn, J. van den Bergh, and J. Opschoor, Economic growth and emissions: reconsidering the empirical basis of environmental kuznets curves. *Ecological Economics,* Vol 25, issue 2, (1998):161–175.

[2] V.lantz, Q.feng, "Assesing income, population, and technology impacts on CO2 emissions in Canada: Where's the EKC?", *Elsivier Ecological economics, Vol 57, Issue 2,* (2005): 229-238, accessed Jun 26th, 2015, http://www.sciencedirect.com/science/article/pii/S092180090500203X

[3] Lucas, R., Wheeler, D., Hettige, H, "Economic development, environmental regulation and the international migration of toxic industrial pollution: 1960–1988. In: Patrick, Low (Ed.)", 75.

Chapter Conclusion

This chapter presented different concepts about the economic growth, economic development and the classical and modern theories that explain the economic growth. Then it shifted to discuss the environment in traditional and modern economic thought, to prove clearly the high importance of considering the environmental side in the development programs for the wellbeing of human beings. The most important finding of this chapter lies in the emergence of a new approach of development called the sustainable development.

The theoretical analyses of the relationship between economic growth and environment have been established under the explanation of the Environmental Kuznets Curve Theory. The fifth chapter includes the application of EKC model for the case of Algeria.

Chapter Three

Chapter Introduction

Economic development forms for our country one of the biggest challenges. Algeria is still trying hard to achieve the goals that have been laid to develop the economy and economy diversification, and improve productivity. In addition, Algeria faces another challenge that lies in the environmental pollution and its economic and environmental consequences. This chapter discusses the economic and environmental situation in Algeria, and thus it has been divided to three parts. The first part investigates the economic growth experiences that Algeria has known. The second part discusses the environmental situation in Algeria. Finally, the third part tackles the efforts that Algeria has done in the field of environmental protection, as well as the local environmental protection laws that Algeria has issued.

3.1.   The Economic Growth in Algeria

The Algerian economy is a hydrocarbon based economy. It is a particular case in the Middle East and North African region. Algeria is vast and rich in natural resources, but these resources' revenues are not well managed to secure a better condition to an economic takeoff.

3.1.1.   Economic Growth Experiences in Algeria

Algeria knew different scenarios of economic growth and development. In the following section, we will see the economic growth trajectory for Algeria from independence until now.

3.1.1.1.   The First Period (1962- 1985)

Since the independence in 1962, Algeria undertook the construction of a socialist economy supported by heavy industrialization and substantial investments in human capital. By the end of the seventies, Algeria was on a strong path of high and fast growing income per-capita and was investing about 45% of the national income. Hydrocarbon exports' revenues funded these efforts, which created a large network for modern public enterprises and helped building extensive infrastructures, and yielded important social progress by reducing illiteracy in addition to increasing life expectancy. The period from 1962 till 1985 is clearly the time when Algeria enjoyed its highest economic growth; averaging 7% annually see (Figure 3-1). This high growth was led principally by the growth in the manufacturing sector, which benefited from intensive public investments.

During the first quadrennial plan (1970-1973), [1] 54% of the total public investments were centered in the fields of industries, mining, energy and hydrocarbons, while agriculture shared only 10% of the same total public investments. The part of investments intended for the industrial sector increased during the second quadrennial plan (1974-1977), reaching more than 56% against only 6% for the agricultural sector. The heavy industry, notably of hydrocarbons see (Figure 3.1), had to guarantee energy and industrial function, as well as a capital accumulation function.

It had to assure accumulation with the help of the oil's revenues, contribute to the construction of the industrial sector by endowing it with raw materials, provide agriculture in inputs and in energy and finally fill a social objective, namely to improve the level of population income and living standards.
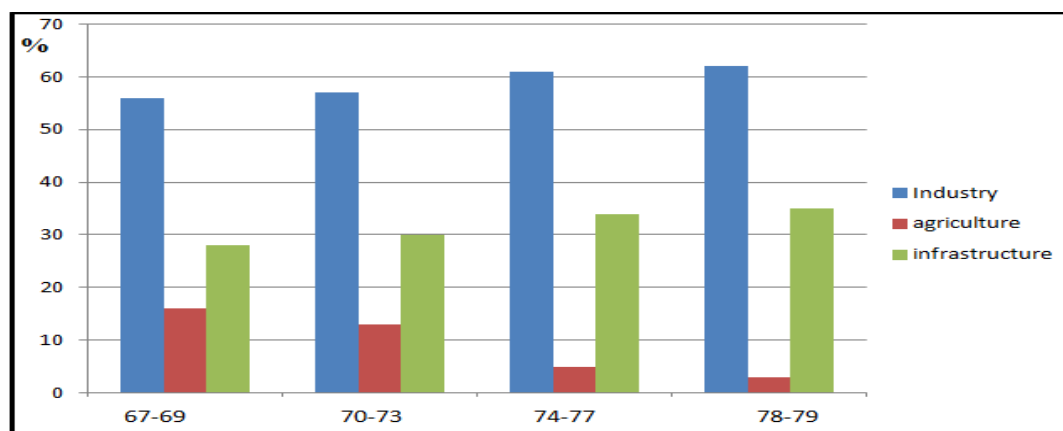
Figure (3.1): The Structure of Completed Investments during the Period of 1967-1979
Source: Benachenhou Abdellatif, *The Algerian Experience of Planning and Development (1962 - 1982),* (Algeria: OPU, 1982), 59.

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[1] Mohamed Abdelbasset, Chemingui, "What Macroeconomics Factors Explain Algeria's Poor Economic Growth Performanc," Background Paper for the GDN Global Research Project on Explaining Growth in Developing Countries: The Case of Algeria,(2003):4, https://www.researchgate.net/profile/Mohamed_Chemingui/publication/228603278_What_Macroec onomics_Factors_Explain_Algeria's_Poor_Economic_Growth_Performance/links/0c96053b7343c4 5d38000000.pdf?origin=publication_detail

3.1.1.2.   The Second Period (1986- 1994)

The steam of the national boom came to a halt in 1986, as oil prices were almost halved compared to 1985, and since then the Algerian economy has kept struggling to recover, as the Algerian Government initially borrowed heavily to compensate for the oil price drop. Real Gross Domestic Product (RGDP) growth averaged less than 1% per year in 1986-1998, compared to 5.4% per year in 1978-1985[1]. The adoption of the structural adjustment program became necessary and was initiated in Algeria in 1987. The program of macro-economic stabilization and structural reform, which was initiated in 1987, ought to be deepened in order to establish the conditions for sustainable long-term growth. The overriding objectives of the macro-economic stabilization program were introduced in order to restore growth.

Over the 1985-1992 period, aggregate GDP growth averaged only 0.4% annually (Figure 3.2). This recession continued in 1993 and 1994. Agriculture has been the bright spot of the economy, averaging an encouraging 5.4% growth rate per year. In contrast, the value added by the core "enterprise sector" (i.e., industry, construction and services) has declined by an average of about 3.2% annually. Limited output growth was rendered into a decline in per capita private consumption of around 3% annually in average over the 1985-1992 period. The recession has worsened unemployment. The number of unemployed workers tripled over that period, and the official unemployment rate reached an estimated 21% of the workforce.

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[1] Ibid.

With the implementation of the 1994 reform program supported by the World Bank (WB) and the International Monetary Fund (IMF), Algeria marked a solid departure from the past, in terms of both macroeconomics policy and results. The program was executed following a severe external payments crisis, after the improvement of the oil prices, which came through in 1993. The Algerian Government introduced swift stabilization and adjustment measures, including a strong fiscal adjustment, tight monetary policy and active exchange rate policy and price liberalization. The program was accompanied by a debt rescheduling agreement with the Paris and London Clubs, and the initiation of structural reforms, including privatization. The main parameters of the reform program have remained in place hitherto[1].
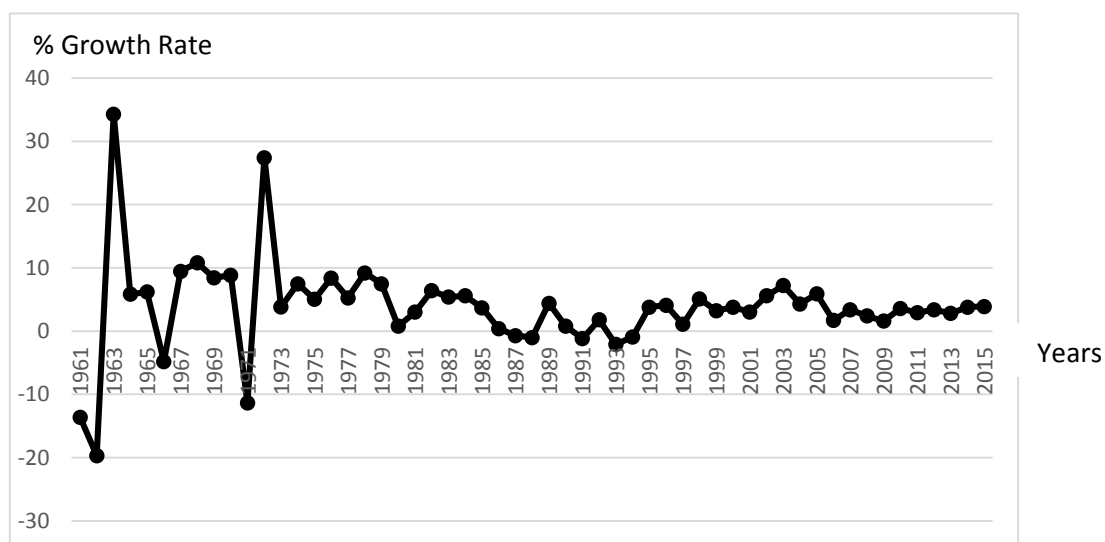
Figure (3.2): Algeria GDP Growth Rate 1961-2015

Source: Compiled by Researcher based on World Bank database.

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[1] Ibid., 3.

3.1.1.3.   The Third Period (1995- 2000)

The reform program, which was supported by the World Bank and IMF and launched in Algeria in 1994, has been highly successful in bringing macroeconomic stability. Inflation dropped from 39% in 1994 to around 5% by the end of the 1990's. The fiscal deficit, which was 8.7% of GDP in 1993, was initially halved and subsequently kept at low levels, and turned into surpluses of around 2.5% by 1997. In 1998, the oil prices dropped again, the fact which weakened the fiscal performance, as the decline in oil revenues provoked a deficit of 4% of GDP, but the fiscal stance was reversed following the oil prices recovery and expenditure reductions in 1999, the fact which yielded a close-to-balanced budget. However, the supply response failed to materialize. The economy remained vulnerable to the changes in the oil prices[1].

3.1.1.4.   The Fourth Period (2000- 2014)

Algeria has generally enjoyed a solidly average GDP growth rates since 2000 (3% on average from 2005 to 2008). Being under the effect of dwindling revenues from hydrocarbon exports, Algeria fell into recession in 2009 with the minimal GDP plunging from $150 billion (2008) to $127.9 billion. As oil and gas prices resurged, the minimal GDP rose again to $153.5 billion in 2010. After the budget surpluses in 2007 (6.1%) and in 2008 (3.4%), Algeria exhibited a deficit in 2009 (-10.6% of GDP). This deficit was able to be narrowed again in 2010, thanks to an impressive surge in liquid natural gas (LNG) export revenues, but still

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[1] Ibid. 3-4.

was not balanced (-4.3% of GDP)[1]. During the period of 2000-2009, Algeria planned for a comprehensive program taking in consideration all development aspects. This plan was divided into two Five-Years Plans; the first Five-Years Plan was applied along the period of 2001-2005. The total financial allocation of this plan was 525 billion DZD. The second Five-Years Plan was applied along the period 2005-2009, and cost 4202.7 billion DZD[2], and it came in order to undertake major structural reforms concerning notably foreign trade, the tax system, state-private sector partnership and civil society. The Five-Years Plan of 2010-2014 includes a substantial public investment component. This plan was approved in August 2010 and has a total financial allocation of 286 billion USD. It is a continuation of the reform programs, which were initiated by the Algerian Government with the backing of the Bank and the Bretton Woods Institutions, to support Algeria's evolution from a planned economy to a market economy[3]. Parallel to economic growth, GDP per capita (PPP) rose to $8,184 in 2009 (2008: $8,002; 2007: $7,769; 2006: $7,445). The government also succeeded in reducing unemployment into digits especially for youths in the late 1990's to around 10% at the end of 2010.

Since the mid-2014, Algeria's fundamentals have steadily worsened, in line with the decline in global oil prices, but the recent budget approved to signal a turning point. In 2015,

[1] BTI , "Algeria Country Report", This report is part of the Bertelsmann Stiftung's Transformation Index (BTI), accessed Jun 27th ,2015, http://www.btiproject.de/fileadmin/Inhalte/reports/2012/pdf/BTI%202012%20Algeria.pdf

[2] Tolmattin Abla , "The impact of climatic changes on the economic growth in Algeria , analytic and empirical study during the period 1980-2009"(Master's thesis, The National School of Statistics and applied economy , Algiers, 2013), 95-98.

[3] African development bank group, "Dialogue Note 2011-2012 for People's Democratic Republic of Algeria," 2013, accessed Jun 28th , (2015):2, https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Algeria-%20Dialogue%20Note%20%202011-2012%20%2801%20juin%202011%29%20Revised%20English%20final.pdf

the economic growth slowed to 2.9 percent from 3.8 percent in 2014 hit by a falling average

in oil prices from US$100 per barrel in 2014 to US$59 per barrel in 2015. Under the initial

expectations that the decline in oil prices would be short-lived, the lack of fiscal consolidation

led the budget deficit to double to -15.9% of GDP in 2015. The current account deficit also

tripled to -15.2% of GDP in 2015. Despite tight monetary policy, inflation rose to 4.8% as a

partial result of pass-through effect from about a 20% minimal devaluation of the Dinar that

aimed to correct the external imbalance. Unemployment rose to double digits.

In December 2015, the government adopted an overdue set of strict policies. The

2016 budget called for a 9 % reduction in expenditure (mostly investment); a 4 % increase

in tax revenue, based on a 36 % growth in gasoline prices and higher taxes on electricity;

gasoline Value Added Tax (VAT) rates and car registrations. The budget empowers finance

authorities to approve further reductions if oil prices fall lower than the average oil prices'

estimation, and to engage in external borrowing if needed. The Government also applied a

new import license and raised electricity prices to become closer to their original

cost. Monetary Authorities allowed the Dinar to be further devaluated, in order to prevent

its misalignments[1].

3.1.2.   Evaluation of Economic Reforms

Despite the efforts engaged in reforms, the results remain mixed. The implementation

of economic reforms has allowed an improvement in the economic indicators of the country

and a bounce back to a higher sustained growth.

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[1]   World   Bank,   Overview   about   Algeria   ,   accessed   Jun   28th   ,   2015,
http://www.worldbank.org/en/country/algeria/overview

However, structural constraints in the economy, including the lack of diversification and the persistence of higher unemployment rate, in particular for youths, are major challenges. The government's attempts to improve the business atmosphere and promote private investments, have not yet achieved the expected results.

In the "Doing Business 2011" report, Algeria was ranked 136th out of 183 countries while in "2016 Doing Business" report, it retreated to 163th out of 189 countries. The main weaknesses lies in the unstable regulatory framework, high transaction costs stemming from time-consuming bureaucratic formalities, the difficulty for Small and Medium Enterprises (SMEs) to obtain bank financing, the inflexibility of labor legislation and the complexity of tax procedures in addition to an important factor, the decline of oil prices.

It should also be noted that the new six measures relating to foreign investment supervisory systems and the import provisions (see Appendix I), which were introduced to supplement previously existing provisions requiring companies established in Algeria to seek funding for their projects preferably from local banks, could have a negative impact on the business environment[1]. It could indeed result in a halt in domestic and foreign private investments, particularly in the industrial and services sectors. To strengthen economic performance over the last decade, Algeria had to continue reforms leading to raise the challenges in terms of improving the business atmosphere, competitiveness and promoting private investments, which are essential for the economic diversification and job creation.

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[1] African development bank group, "Dialogue Note 2011-2012 for People's Democratic Republic of Algeria,"2.

3.1.2.1.   The Economic Growth According to Different Economic Sector

The Algerian economy remains highly dependent on the oil and gas sector and therefore very sensitive to external shocks. From 2004 to 2010, the country's GDP growth rate averaged to 3.4%, driven by the performance of the oil and gas sector, as well as the contribution of the services, construction and public works sectors and, to a lesser extent, the agricultural sector, which recorded a bumper cereal harvest in 2009. The vitality of the services and construction sectors stems mainly from the huge volume of public investments. The vitality of these sectors is reflected in the relatively high non-oil GDP growth rate, which stood at 6.3% per annum during the period 2004-2010. However, its contribution to GDP is still low. Its real constraint lies in facing the challenge of diversification of income sources of the country. Since 2015, Algiers has strengthened protectionist measures to limit its import bill and encourage domestic production of non-oil and gas industries. The falling oil prices caused huge declining of revenues, and the government has been under pressure to reduce expenditure.
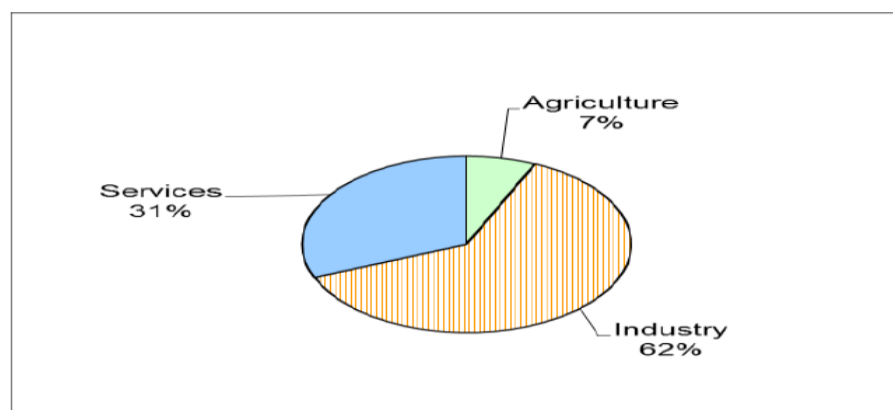
Figure (3.3): GDP by Sector 2009

Source: African development bank group, "Dialogue Note 2011-2012 for People's Democratic Republic of Algeria,"2.

At the sectoral level, agricultural production increased in 2010 by about 8.5%, against 9% in 2009, despite a tight decrease of the sectoral growth, reflecting an exceptional production growth due to favorable climatic conditions and the acceleration in the implementation of the agricultural and rural renewal plan. In addition, the different recovery programs and support to growth have allowed the construction sector, which accounted for nearly 10% of GDP in 2010[1], to register a growth of about 10% over the last five years. The services sector, with a GDP contribution of about 26%, recorded an average growth of 9% during the same period. Despite the decline in global demand and prices of oil observed in 2009, under the impact of the global economic crisis, GDP growth remained stable at 2.4%, due to the good performance in others sectors. In 2010, with the resumption of economic activity and rising global oil prices that succeeded, growth stood at 3.5%. Meanwhile, non-oil growth was stronger setting at 9.3% in 2009 and 5.5% in 2010. The medium term growth prospects promised to be favorable at 3.9% in 2011 and 3.6% in 2012. The economic growth rate of GDP remained modest during the last five years (2011: 2.9% , 2012: 3.4% , 2013: 2.8% , 2014: 3.8% , 2015: 3.9)

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[1] Ibid.
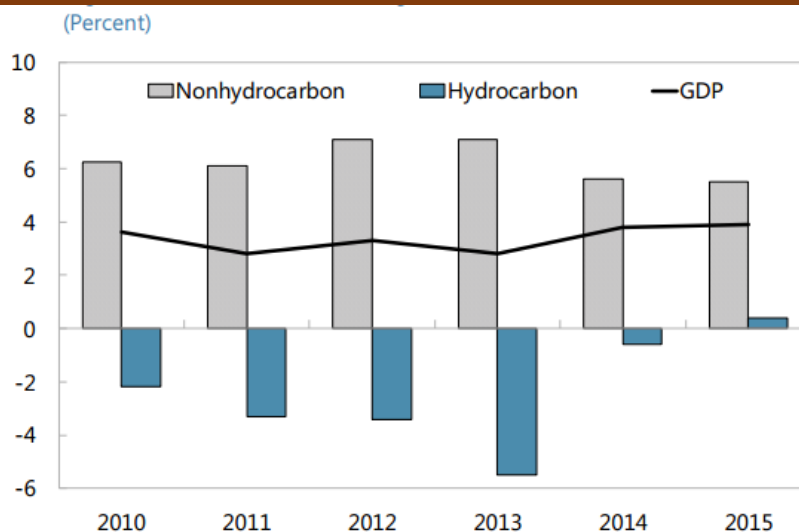
Figure (3.4): Hydrocarbon and Nonhydrocarbon Growth

Sources: Algeria IMF Report, (2016): 7, accessed Jun, 29th ,2015, 07. http://www.imf.org/external/pubs/ft/scr/2016/cr16127.pdf

The hydrocarbon sector rebounded as new fields came on stream, while nonhydrocarbon growth was steady. Despite the reforms adopted to promote exports outside the hydrocarbon sector, but non-hydrocarbon growth rate production did not exceed 4% as average. Nonhydrocarbon growth initially slows under the effects of fiscal consolidation but eventually accelerates partly as structural reforms started being fruitful. With hydrocarbon revenues significantly reduced, Algeria needs to mobilize more nonhydrocarbon revenues[1].

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[1] 2016 Algeria IMF report, 7-14, accessed Jun, 29th ,2015, http://www.imf.org/external/pubs/ft/scr/2016/cr16127.pdf
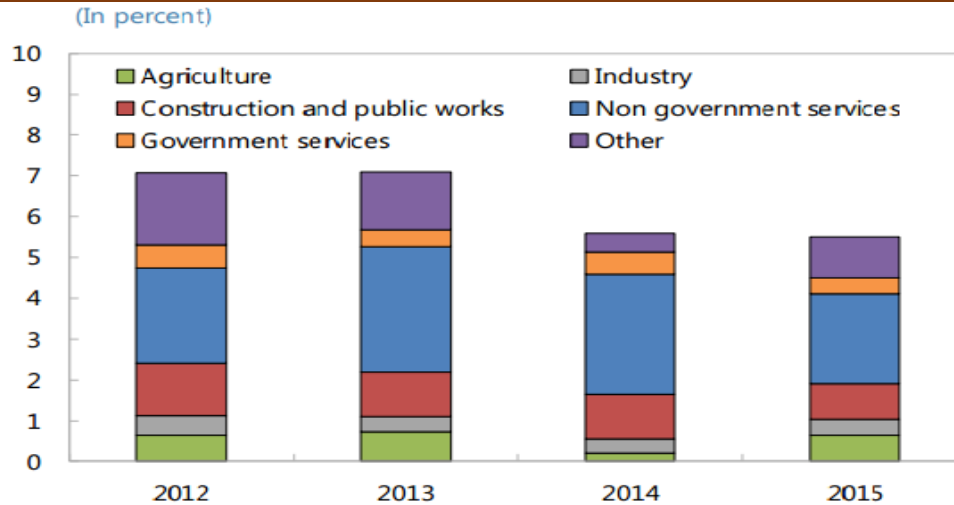
Figure (3.5): Sources of Nonhydrocarbon Growth

Source: 2016 Algeria IMF Report, 7.

Stronger growth in the agricultural sector helped offset weaker activity in the construction and services sectors. Although the efforts of the government to improve the growth out of the hydrocarbon sector, but its the growth rate is still modest, because of the obstacles in the investment field. The "2016 Doing Business" report showed that and suggested that Algeria should ease these procedures to move towards its designed goals.

3.1.3.   The Environment in Algerian Development Agenda

After independence, Algeria's emphasis was to reconstruct what the colonialists left, so, it neglected the environmental side to a far extent, the fact which led to a shift of different ministerial sectors to take responsibility of the environmental field up till 2000. This created instability in environmental management and vague activity consequences, the fact that worsened the urban and industrial pollution and speeded up natural environmental deterioration. The Algerian authorities have funded environmental management projects

since 2000[1]. Beforehand, the environmental awareness had taken a backseat in the growth considerations during post-independence development; this was most prominently reflected in the efforts to build up a heavy industry in the 1970s.

There have been attempts since the 1970s to stop desertification, though projects such as "La Ligne Verte" (The Green Line) which knew a partial success. Since 2000, the Algerian Government has provided an increase in the attention given to environmental protection projects, for instance, by setting up a funding facility (l'Agence National pour la Protection de l'Environnement) in 2001. Within the framework of the development plan "National Scheme of Special Planning 2025" (NSSP 2025), the government foresees more measures to improve waste disposal, promote the water and sewage sectors. Around 40 sewage treatment plants have been scheduled for construction and 20 others for restoration, the fact which will raise the treatment capacity to 600 million cubic meters per year.

The plan also included the construction of 13 seawater desalination plants, two of which are already in service (in Arzew and Algiers). In the fight against air pollution and greenhouse gas emissions, the Algerian government has a good share in issuing laws, though it did not provide particular incentives for households and companies to engage in an environmentally sound consumption and investment behavior.

Algeria is taking part in the (Desertec) initiative project, which aims to create a network of solar and wind power-generating projects across North Africa in order to meet the supply of 15% of Europe's electricity needs by 2050[2]. In this context, the government

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[1]   BTI   ,   "Algeria   Country   Report",
http://www.btiproject.de/fileadmin/Inhalte/reports/2012/pdf/BTI%202012%20Algeria.pdf
[2] Ibid.

announced a plan in early 2011 according to which Algeria will generate 40% of its electricity needs from renewable sources by 2030 to meet domestic demands and to export clean power to Europe. In the first phase (until 2020), about 65 projects are planned and are expected to generate 200,000 jobs. A first German-Algerian joint venture for the creation of photovoltaic wafers in Rouiba near Algiers was contracted in early 2011 and launched in 2012.

3.2.   The Environmental Situation in Algeria

3.2.1.   Some Social and Environmental Indicators about Algeria

Algeria is one of the Mediterranean countries. It is located in North Africa, as a gateway between Africa and Europe, and it possesses a wonderful seafront extended along 1200 km. The country is bordered on the east by Tunisia and Libya, on the west by Morocco and Western Sahara and on the South by Mali, Niger and Mauritania. Algeria is the first largest country in Africa and tenth-largest country in the world, with a territory of 2,381,741 km². It consists of 48 provinces and 1541 communes, in which inhabits a population of more than 38.9 million people[1]. However, this large territory is eaten by the desert of Sahara, leaving only a narrow ribbon of 1,000 × 100 km along the Mediterranean Sea[2] (see Figure 3-1). In addition to this, more than 80% of this area gathers more than 85% of the population. Fortunately, the huge Sahara, which seems useless and wasted, is full of precious products and raw materials such as oil, gas, gold, uranium, phosphate, iron, and even agrarian fields. This territory, with unbalanced use, makes the planning and management of the country difficult, besides raising the difficulty of ensuring social justice. The climate is mainly

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[1] Ibid.

[2] Mokhtar Kheladi, Baya Arhab, "The Transition to a Market Economy: The Experience of Algeria", *China-USA Business Review*, Vol. 11, (2012): 299, accessed Jun 29th ,2015 http://www.davidpublishing.com/davidpublishing/Upfile/4/10/2012/2012041068106105.pdf

Mediterranean in the northern and coastal regions, continental in the hinterland, and tropical in the south with large variations in temperature between day and night.

Figure (3.6): Algeria Geography

Source: Maps.com, accessed Jun 30, 2015. http://www.maps.com/ref_map.aspx?pid=11874.

Algeria is one of the major exporters of oil and gas, and is ranked as the 14th largest world exporter of oil, and supplies almost 20% of Europe's natural gas needs. The oil and gas sector dominates the economy, accounting on average of 43% of GDP, 98% of exports and 75% of budget revenues. Algeria has huge and considerable gas and oil reserves. It is estimated and proved that oil reserves stand at 11.8 billion barrels, while the total of those of natural gas are about 4.5 billion m^3, placing the country in the 7th rank in the world[1].

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[1] African development bank group, "Dialogue Note 2011-2012 for People's Democratic Republic of Algeria,"4.

3.2.1.1.   Algerian Demographics

The population growth is considered as the engine of many environmental problems. It increases the demand for environmental resources such as water, lands…etc. on one hand, and increases the wastes and pollution on the other.
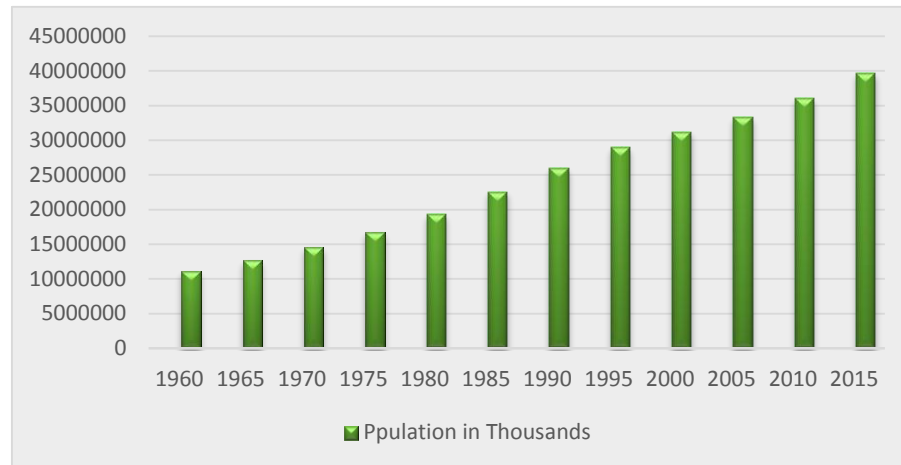
Figure (3.7): Population Growth of Algeria 1960-2015

Source: Compiled by the researcher based on World Bank database

Since the eighties, Algeria's population growth rate dropped gradually. In 1990, the population growth rate was 1.6% and from that year the population growth rate stopped increasing instead it started to slow down. In 2005, the population growth rate was 0.80% and in 2015 was 0.7%. This continuous decrease in population growth rate is due to several factors, such as the increase in women literacy in Algeria, the introduction of modern life standards, unemployment, increase of prices...etc.

Table (3. 1): Algeria Population Distribution by Region in (1998, 2008)

Area	Distribution % (1998)	Distribution % (2008)	Surface km^2	Surface (%)	Population density (Inhabitants /km^2) 1998	Population density (Inhabitants /km^2) 2008
North	64.7	63.13	102781	4.32	183.18	209.29
High plateaus	26.50	27.37	303231	12.73	25.43	30.75
South	8.80	9.51	1975729	82.95	1.30	1.64
Total	100.00	100.00	2381741	100	12.22	14.31

Source: The Algerian Ministry of Environment and Land Use Planning (MELUP), Second National Communication of Algeria on Climate Changes, Algiers, 2010, 33.

It is illustrated through Table (3.1) , that more than 63.3% of Algeria's population lives in 4% of the national territory, and 27.37 % of the total population lives in 13% of Algeria's surface (high plateaus), while less than 10% of the total population lives in more than 82.95 % of Algeria's flat surface in the Sahara Desert. We can imagine the seriousness of this inequality distribution of Algeria's population, which creates many environmental and economic problems.
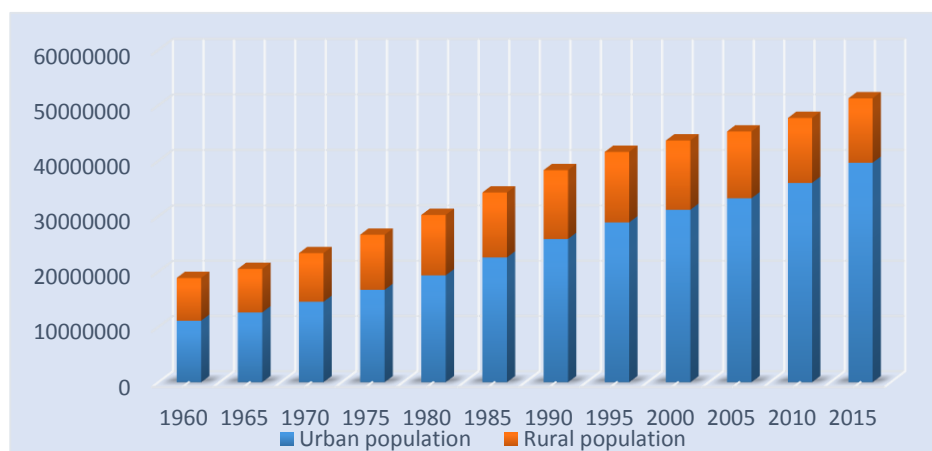
Figure (3.8): The Development of Urban and Rural Population
Source: Compiled by the Researcher based on the World Bank database

The proportion of rural population to the total population dropped increasingly. In 1965, the proportion of rural population to the total population was 62% and moved down to 47% in 1990. That happened because of centralization of economic activities in the cities and the lack of job opportunities in the rural areas. The period 1990-2000 witnessed a significant rural exodus due to the hard security situation (The Black Decade), in addition to the previous reasons, to reach 29% by the end of 2015.

This substantial rural exodus creates many complex problems in the cities. Among these problems -but not limited to:

✓   Terrible expansion of cities and the distort of its shape because of "Slum*".

✓   The complex transportation problem.

✓   The complex social epidemics such as crimes and begging.

3.2.1.2.   Human Development Index

Algeria's Human Development Index value for 2014 was 0.736[1], the fact which put the country in the high human development category positioning it at 83 out of 188 countries and territories, compared to 2009 HDI, where it ranked 84th position out of 169 countries. Between 1990 and 2014, Algeria's HDI value increased from 0.574 to 0.736, an increase of 28.2 % or an average annual increase of about 1.04 %. Algeria has been classified as one of the "Highly Developed" African countries.

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* A **Slum** is a heavily populated urban informal settlement characterized by substandard housing and squalor.
[1] *UN, 2015 Algeria Human Development Report.*

The following table reviews Algeria's progress in each of the HDI indicators. Between 1980 and 2014, Algeria's life expectancy at birth increased by 16.6 years. The average years of schooling increased by 5.8 years and expected years of schooling increased by 4.5 years. Algeria's GNI per capita increased by about 31.1 percent between 1980 and 2014.

Table (3-2): Algeria's HDI Trends Based on Consistent Time Series Data and New Goalposts

Year	Life expectancy at birth	Expected years of schooling	Mean years of schooling	GNI per capita (2011 PPP$)	HDI value
1980	58.2		1.8	9.975	
1985	64.1		2.6	11.003	
1990	66.7	9.5	3.6	9.772	0.574
1995	68.1	9.6	4.7	8.689	0.596
2000	70.2	10.7	5.9	9.569	0.640
2005	72.2	12.0	6.9	11.487	0.687
2010	73.8	13.6	7.6	12.478	0.725
2011	74.1	14.0	7.6	12.486	0.730
2012	74.3	14.0	7.6	12.657	0.732
2013	74.6	14.0	7.6	12.771	0.734
2014	74.8	14.0	7.6	13.054	0.736

Source: UN, 2015 Algeria Human Development Report, accessed September 20th , 2015, http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/DZA.pdf

Algeria is placed well above the regional average (HDI increase from 0.574 in 1995 to 0.736 in 2014)[1]. Not surprisingly, according to 2015 Human Development Report, Algeria ranks behind oil-rich Gulf countries, however, given the country's wealth in hydrocarbons, although the dropped of revenues because of the slump of oil prices. This development of HDI in Algeria is a result of the Algerian government efforts to improve the living conditions for Algerian citizens through improving the three parts of HDI (education, health and income), following a package of policies and providing finance to public services. The education in Algeria is free and compulsory especially for the basic educational levels to reduce the percentage of illiteracy and to build human capital. In addition, the medical care is free and has a good share from public finance. The Algerian government also seeks to reduce the unemployment and eliminate poverty through supporting the private sector projects in order to create job opportunities for Algerian youth.
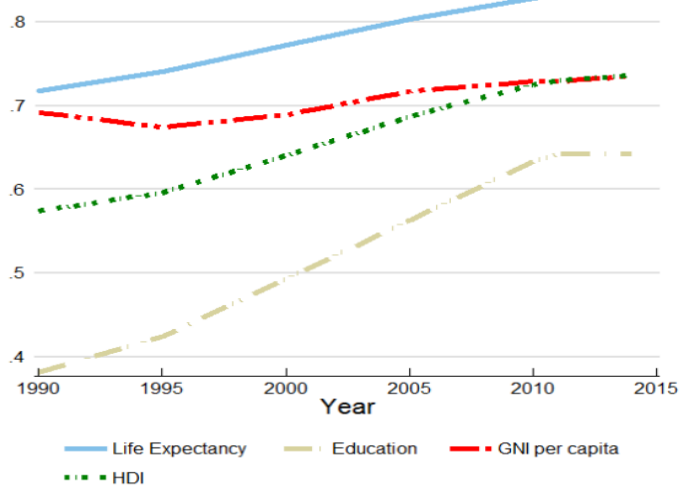
Figure (3.9): Trends in Algeria's HDI and its Component Indices 1990-2014

Source: UN, Algeria 2015 Human Development Report.

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[1] UN, 2015 Algeria Human Development Report, accessed September 20th , 2015, http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/DZA.pdf

3.2.1.3.   Some Environmental Indices about Algeria

Generally speaking, most of the environmental issues which have priority in Algeria do not differ from others raised in the Arab countries .These issues include: water scarcity, water pollution, desertification, air pollution, the ever growing energy consumption, its impact on environment, land degradation and forests loss…etc.

Table (3. 3) Environmental Indices for Some Arab Countries

Country	ESI	EPI		Country	ESI	EPI	
	2005	2005	2010		2005	2005	2010
Algeria	46.0	66.2	67.4	Morocco	44.8	64.1	65.6
Egypt	44.0	57.9	62.0	Oman	47.9	67.9	45.9
Iraq	33.6	N/A	41.0	KSA	37.8	68.3	55.3
Jordan	47.8	64.1	56.1	Sudan	35.9	44.0	47.1
Kuwait	36.6	N/A	51.1	Syria	43.8	55.3	64.6
Lebanon	40.5	76.7	57.9	Tunisia	51.8	60.0	60.6
Libya	42.3	N/A	50.1	UAE	44.6	73.2	40.7
Mauritania	42.6	32.0	33.7	Yemen	37.3	45.2	48.3

Source: Gulf investment weekly economic digest, Volume 2, (2012), accessed Jun September 23rd 2015, https://www.gic.com.kw/site_media/uploads/gic_wed_94-107/gicwed99.pdf

➢   **The Environmental Sustainability Index (ESI)**

The 2005 Environmental Sustainability Index (ESI) provided a composite profile of national environmental stewardship based on a compilation of 21 indicators, that derived from 76 underlying data sets of environmental sustainability. That covers the natural resource endowments, past and present pollution levels, environmental management efforts, the contributions in protecting the global commons, in addition to the society's capacity to improve its environmental performance over time. Algeria ranked as the fourth among the

MENA countries and seventieth[1] in the world. The desertification is one of the strongest threats of environmental sustainability in Algeria.

➢ **The Environmental Performance Index (EPI)**

The recurrent editions of the Environmental Performance Index (EPI) provided a measure of how Algeria has been taking a more committed stance on integrating established environmental policy goals. In the 2010 EPI edition[2], Algeria topped the Middle East and North African countries, when it ranked 42nd out of 163 nations, making the country a relative champion by regional standards (Morocco: 52, Tunisia: 74, Egypt: 68, Libya: 117, Mauritania: 161). This reflected the Algerian government efforts in the environmental field and its desire to improve the environmental situation under the methodological followed sustainable development framework. In 2016 EPI report edition, Algeria ranked 83rd among 180 nation and territories with a score of 70.28[3], and that was because of the decrease in the government revenues that caused the funding for different projects to fall down, including environmental projects. In spite of the fall back in Algeria's rank, the Peer Comparison Column in the EPI 2016 rankings table identified that it has a better performance than countries in its region.

➢ **The Climate Change Performance Index (CCPI)**

The Climate Change Performance Index (CCPI) is a tool designed to enhance transparency in international climate politics. Its purpose is to put political and social pressure

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[1] Environmental Sustainability Index report, (2005),   accessed September 25th, 2015, http://www.yale.edu/esi/ESI2005_Main_Report.pdf
[2] Environmental Performance Index report, (2010), accessed September 25th, 2015, http://ciesin.columbia.edu/repository/epi/data/2010EPI_summary.pdf
[3] Environmental Performance Index report, (2016), accessed September 26th, 2015, http://www.indiaenvironmentportal.org.in/files/file/Yale%20EPI%202016_Report.pdf

on those nations which have, up until now, miscarried to take ambitious action on climate protection. It also aims to highlight those nations with the best-practice climate policies. According to this index Algeria is ranked 40[th][1] with a score of 53.30 in the same category with Norway, Poland, United States and New Zealand. Although in the overall ranking it was ranked in the poor performing countries, but it still had an improvement in the index level comparing with previous years. The report concluded that no country is doing enough to prevent dangerous climate change and suggested to make greater efforts to protect our shared planet.

3.2.2.   The Environmental Pollution in Algeria

The environmental pollution problems in Algeria were associated with the advocating economic and social development policies. From independence until the eighties (1962-1980s), the environmental problems were ignored in developmental programs. In the last two decades Algeria's attitude changed because of the serious deterioration in the Algerian environment. The environmental damage is considered to inflict huge consequences at the expense of several social standards, such as the impact on public health, quality of life, and inefficiencies on the natural capital. These costs were estimated in 2002 to be around 7% of GDP or 3.5 billion US dollars, while in 2007, these costs decreased significantly to 5.21 % of GDP or 2.6 billion US dollars (see Figure 3.10). This improvement in environmental quality in Algeria is due to the implemented environmental policy under the frame of sustainable development program.

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[1] Climate Action Network Europe, The Climate Change Performance Index, accessed September 26th, 2015, https://germanwatch.org/en/download/13626.pdf
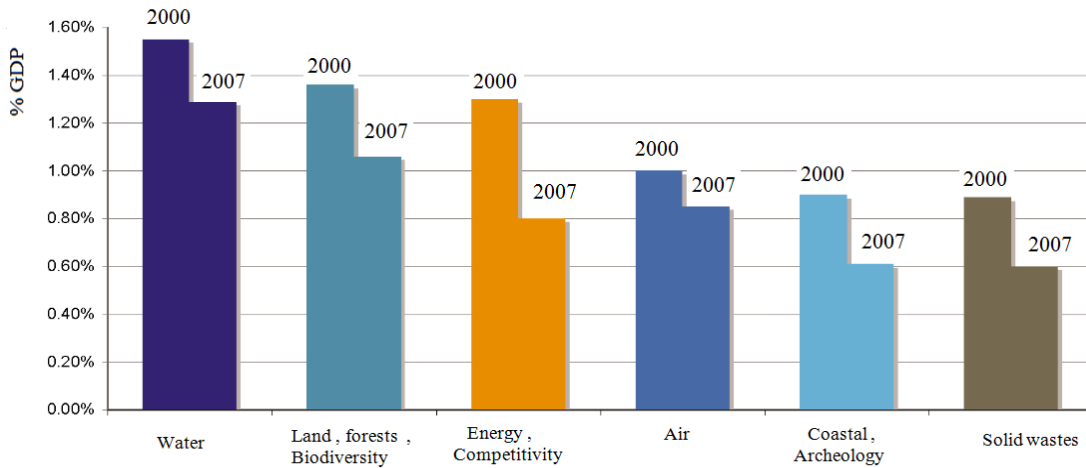
Figure (3.10): The Evaluation of Environmental Damage Cost in Algeria for 2000 and 2007

Source: National Report about the Environmental Status of 2007.

3.2.2.1.   Air Pollution in Algeria

The problem of air pollution in Algeria is accompanied with economic and social development. According to 2010 environmental national report, Algeria air pollution is basically a result of energy consumption and transportation, the latter is considered to be one of the most important factors responsible for air pollution in big cities in Algeria. That is due to obsolescence of cars, where we find more than 58%[1] of cars exceeding the age of 20 years being still in use. The following figure shows the automobile fleet by age group in Algeria, pointing out that 63% of vehicles have been in use for more than 15 years by December 2010.

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[1] National Office of Statistics, 2015 Environmental Statistics Report, 55.
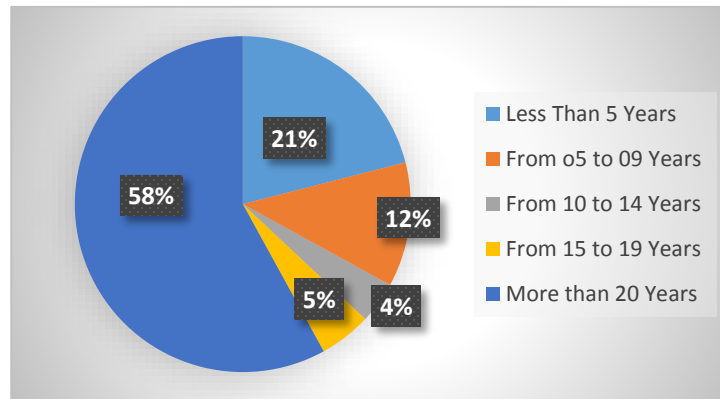
Figure (3.11): Distribution of Vehicle Fleet by Age in 2010

 Source: National Statistics Office (NSO), 2015 Environmental Statistics Report, 55.

The transportation sector in Algeria depends entirely on oil usage (gasoline, diesel). Gasoline has been the main source of energy for more than 74%[1] of vehicles. The other 26% are running on diesel. The number of vehicles converted to liquid petroleum gas (LPG) is estimated to be only 120,000, which represent 4% of the car fleet. The main generated pollutants are Nitrogen oxides (NOx), Carbon monoxide (CO), Carbon dioxide (CO_2), Volatile organic compounds (VOCs), Particulate matter (PM) and Lead. The statistics of 2000 showed that these emissions are generated from:

✓   Energy with 74.7%,

✓   Agriculture and forests 10.9%,

✓   Solid wastes 9.7%,

✓   Industrial processes.

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[1] The Algerian Ministry of Energy and Mines, Report related to air pollution, accessed Aug 23rd   ,2015, http://www.memalgeria.org/actu/comn/JourneGazoil/Rapport_%20pollution_Gazoil_MATET.ppt

As for Co$_2$ emissions specifically, the following figure shows the responsible sectors

for it:
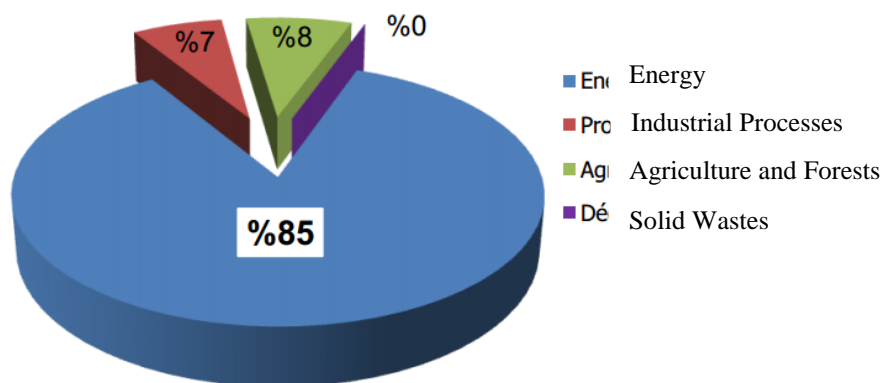
Figure (3-12): Distribution of CO$_2$ Emissions by Sector in 2000

Source: National Statistics Office (NSO), 2015 Environmental Statistics Report, 49.

✓   **The Impact of Atmospheric Pollution on Health in Algeria**

The air pollution in Algeria has reached alarming proportions that constitute a danger

on the air quality and the population health. The polluted air spreads over long distances and

can practically not be avoided. The impacts on human health could be the most drastic since

human lungs contain very sensitive tissues. The rate of children mortality in Algeria (children

under one year) has known reduction from 149.1 per 1,000 live births in 1965 to 21.9 per

1,000 live births in 2015[1] (see figure 03.13), 30% of consultations concerns the respiratory

diseases[2]. The high concentration of smoke and dust in the air is responsible for more than

300,000 to 700.00 annually early death cases and 600,000 permanent asthmatics patients.

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[1] World Bank Database, available at: http://data.albankaldawli.org/indicator/sp.dyn.imrt.in
[2] The Algerian Ministry of Energy and Mines, Report related to air pollution, available at : http://www.memalgeria.org/actu/comn/JourneGazoil/Rapport_%20pollution_Gazoil_MATET.ppt

Because of these reasons it is urgent to monitor the air quality and assess the actual degree of pollution generated in the urban areas. The annually environmental cost of air pollution in Algeria is estimated to be 0.9% of GDP. The yearly concentration of PM10 in one of the most polluted cities in Algeria (Algiers) is around 50 microgram in a cubic meter, 180 microgram in a cubic meter for the Ozone is, 400 microgram in a cubic meter for Nitrogen oxides and 360 microgram in a cubic meter for the concentration of CO_2. It is emitted on the roads in the capital with quantities of lead estimated by 180 ton per year. The other cities in Algeria also suffer from degradation in the quality of air but on a smaller scope.
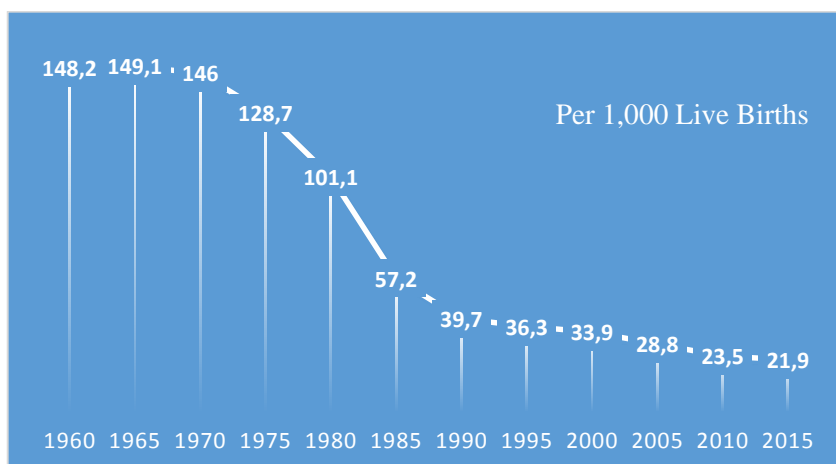
Figure (3.13): Infant mortality Per 1000 Live Births in Algeria

Source: Compiled by the researcher based on the World Bank Database

✓   **Algeria's Efforts in Reducing Air Pollution**

As a member in the United Nations Framework Convention on Climate Change (CFCCC), in 1993, Algeria approved to reduce the emissions of Greenhouse Gases (GHG). In order to meet its requirements towards (CFCCC), the first national report was issued in 2001 then the 2nd national report in 2010, to record the emission of (GHG) revealing the

responsible sectors for these emissions. It is worth to note that in recent years, the decrease of levels of lead in gasoline from 0.6 to 0.4 g/liter resulted a significant drop in lead emissions in Algeria[1].

The polluted emissions pose a threat on people and the environment, the fact that requires the necessity of putting all the needed arrangements and legislation framework to reduce pollution. Algeria is following a national environmental strategy under the sustainable development framework, through establishing institutional tools such as[2] the national center of clean technologies for production and the National Observatory for Environment and sustainable development. Algeria issued several laws and decrees to decrease air pollution, and some of these are mentioned as follows:

✓   Executive Decree No. 90-78 issued in February 1990 concerning studies about the impacts of pollution on the environment[3].

✓   The law No.03-10 issued in 19 July 2003 relating to environmental protection under the sustainable development program framework. It stipulates the quality of buildings, industrial plants, commercial and agricultural activities as well as vehicles or other movable objects. In order to protect the environment by preventing the air pollution from its sources or at least reduce it[4].

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[1] National Report about the environmental status, "The Algerian Ministry of Environment and Land Use Planning (MELUP)", 2007, 55.

[2] The Algerian Ministry of Energy and Mines, Report related to air pollution, accessed September 28th ,2015, http://www.mem-algeria.org/actu/comn/JourneGazoil/Rapport_%20pollution_Gazoil_MATET.ppt

[3] Algerian Official Journal, number 10, Executive Decree n ° 90-78, 27 February, 1990.

[4] Algerian Official Journal, number 43, Law n ° 03-10 du 20 July, 2003.

✓   Executive Decree No. 06-02 issued in 7 January 2006 defined the limiting values that alert the thresholds and objectives of air quality in the case of air pollution[1].

✓   Executive Decree No. 06-138 issued in 15 April 2006 regulating the emitted emissions into the atmosphere such as gases, smoke, fumes, liquid or solid particles and the conditions to control it[2].

✓   Executive Decree No. 06-198 issued in 31 May 2006 defined the regulations and classified facilities directed to protection of the environment[3].

These laws also impose for the public authorities obligations to control the air quality at the level of gatherings (more than 500,000 inhabitants), depending on the following planning tools:

- Regional Plan for Air Quality (RPAQ).

- Climate Protection Plan (CPP).

- Urban Transport Planning (UTP).

In order to measure the air pollution in hot spots in Algeria, the Ministry of Environment has established a monitoring network measuring the air pollution called (SAMASAFIA). Currently the installation of this network has been carried out in four big cities[4], Algiers, Annaba, Oran and Skikda. The project is still practical for expansion.

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[1] Algerian Official Journal, number 01, Executive Decree n ° 06-02, 7 January, 2006.
[2] Algerian Official Journal, number 24, Executive Decree n ° 06-138, 15 April 2006.
[3] Algerian Official Journal, number 36, Executive Decree n ° 06-198, 31 May 2006.
[4] The Algerian Ministry of Energy and Mines, Report related to air pollution, accessed 28th ,2015, http://www.mem-algeria.org/actu/comn/JourneGazoil/Rapport_%20pollution_Gazoil_MATET.ppt

3.2.2.2.   Water Pollution in Algeria

Algeria is classified as a country with a problem of water scarcity. The water supply in Algeria has an adverse relationship with the demographic growth, as per capita renewable water resources knew a decline from 480 cubic meters in 1987 to 384 m^3 in 1997 and is currently less than 320 m^3 for the population, the fact which led to a decrease with a yearly growth rate of around 1.4%. The annual per capita water scarcity threshold is 1,000 cubic meters[1]. Agricultural irrigation is the primary water consuming sector followed by the domestic and industrial sectors. Water allocated for irrigation has dropped from 80 percent in 1960 to around 60 percent in 2002. The National Plan for environment and sustainable development (NPE-SD) assessment for water damage in 2007 showed that 0.69% of GDP is due to the weaknesses in the sanitation management. Furthermore, the national report about the environmental status of 2007[2] added that without significant improvement in the sanitation management, these impacts and costs would become hard to diminish in future, knowing that water pollution has serious impacts on the public health and the widespread of diseases.

➢ **The Coastal Water Pollution**

The large concentration of population and industrial activities in the coast line led to a high impact on the coastal environment where it costs a loss of about 17% of the total area

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[1] Mediterranean Environmental Technical Assistance Program .Water Quality Management in Algeria report, accessed 28th ,2015, http://siteresources.worldbank.org/EXTMETAP/Resources/WQM-AlgeriaP.pdf

[2] National report about the environmental status, The Algerian Ministry of Environment and Land Use Planning, 56.

of Algeria's beaches. More than 96%[1] of foreign trade transactions with the world are done by sea. The marine pollution generated by the industrial poles is recorded at alarming proportions especially petroleum spills, where annually around 100 million tons of hydrocarbons pass near the Algerian beaches, while 50 million tonnes are shipped annually from the Algerian ports, but unfortunately more than 10000 tons are lost and leaked into the sea during these transactions[2].

According to 2007 environmental status report, the amount of wastewater that reaches to sea without treatment is still important. The coastal areas are adjacent with large population and industrial ports. It receives streams of pollution from several sources, some of which we mention as follows:

➢   Most water resources in Algeria are polluted as a result of uncontrolled and untreated municipal wastewater. 87% of the urban population is connected to a poor sewage network, but most of the wastewater treatment plants are out of service, so untreated sewage is being discharged into natural water bodies[3].

➢   The discharge of chemical and petrochemical industrial wastes in the sea such as heavy metals, detergents, organ phosphorus, fiber materials and other chemical compounds, all these chemical pollutants mostly come from the industries located in Algiers and other industrial coastal cities like Arzew, Mostaganem, Skikda…etc. The overall of the

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[1] African development bank group, "Dialogue Note 2011-2012 for People's Democratic Republic of Algeria,"2.
[2] Siham Blqurmi, " Algeria's experience in environmental protection", (Messila: University of Msila, 2009), accessed September 23rd ,2015, http://sciencesjuridiques.ahlamontada.net/t502-topic
[3] Mediterranean Environmental Technical Assistance Program .Water Quality Management in Algeria report, accessed September 23rd ,2015, http://siteresources.worldbank.org/EXTMETAP/Resources/WQM-AlgeriaP.pdf

metropolitan area of Algiers receives the largest proportion of pollution flows which reach to the sea.

➢ Discharges from thermal power plants in Marsat El Hadjadj, Algiers and Cape Djinet[1].

On the national territory, 934,250[2] economic entities were enumerated during the first economic census carried out in 2011. More than 46% of these entities are located in the littoral zone with a considerable concentration in the provinces of Algiers and Oran, which recorded 10.38 % and 5.66 % respectively of all economic entities.
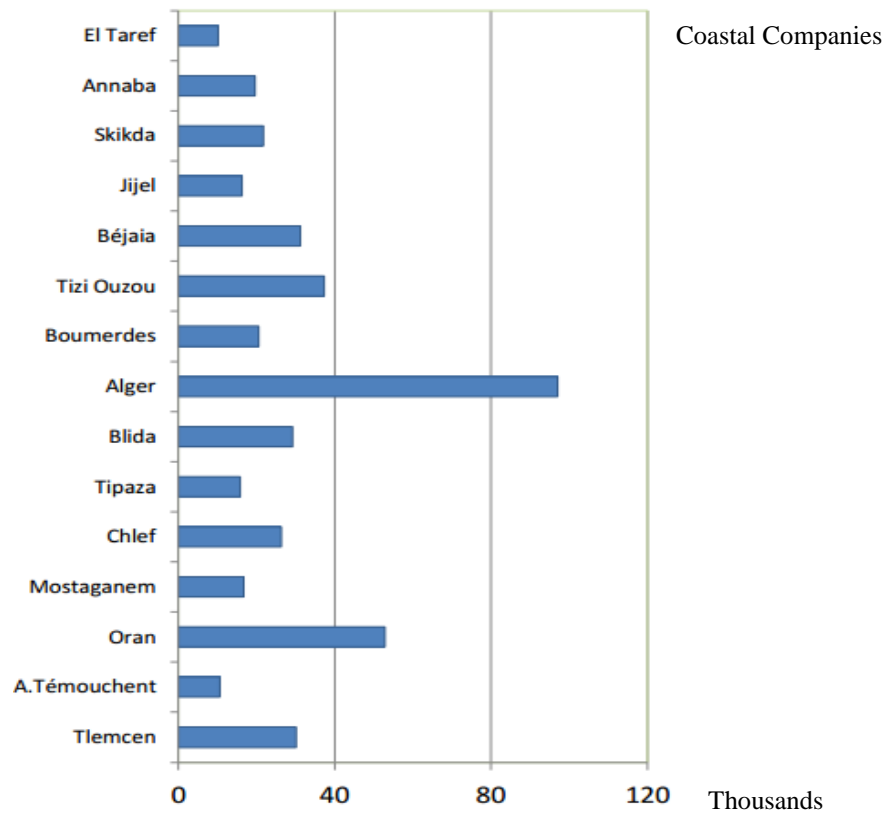
Figure (3.14): The Distribution of Economic Companies on the Algerian Coastline
Source: National Office of Statistics, "2015 Environmental Statistics Report", 28.

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[1] National report about the environmental status, The Algerian Ministry of Environment and Land Use Planning, 57.
[2] National Office of Statistics, "2015 Environmental Statistics Report", 28.

This huge concentration of economic companies in the coastal line pollutes the seawater and increases the number of beaches, which are banned for swimming. The results of physicochemical analysis obtained by the services of the National Observatory of the Environment and Sustainable Development concerning 125 beaches[1], during the summer period of 2009, revealed the following:

✓   81 beaches were of good quality (65%).

✓   18 beaches were of acceptable quality (14%).

✓   26 beaches had insufficient results (21%).

✓   12 beaches had a bad quality (9.6%).

➢   **Sanitation and Wastewater Treatment:** The wastewater produced by different sectors is the source of water pollution for the natural environment. The role of sanitation is preserving soil and water reserves. The following table presents the national population connected to public sewerage networks and wastewater treatment plants.

Table (3.4): Population Connected to a Sanitation Network and Wastewater Treatment (%)

Years (20-)	2000	01	02	03	04	05	06	07	08	09
The connected population to a system of collection of urban wastewater	71	71	71	71	72	72	72	74	75	76
The connected population to facilities treatment of urban wastewater	30	30	32	32	39	39	45	48	53	56
Population with independent sewage treatment facilities (for example Septic tanks)	10	10	10	12	12	16	16	18	15	14

Source: National Office of Statistics, "2015 Environmental Statistics Report", 23.

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[1] Ibid., 33.

The estimation of pollutants inflows and the total pollution indicators always indicate a weak waste management in Algeria, where the daily quantity of wastewater discharged in port sites is 1,053,907.2 square meters[1]. These wastewaters discharged into the harbor sites are virtually untreated. As for the production of BOD and COD, the report indicated that the yearly level of these two pollutants at least still maintained unchanged (see Figure 3.14). These pollutants amounts respectively are 88,205 tons per year and 186,322 tons per year.
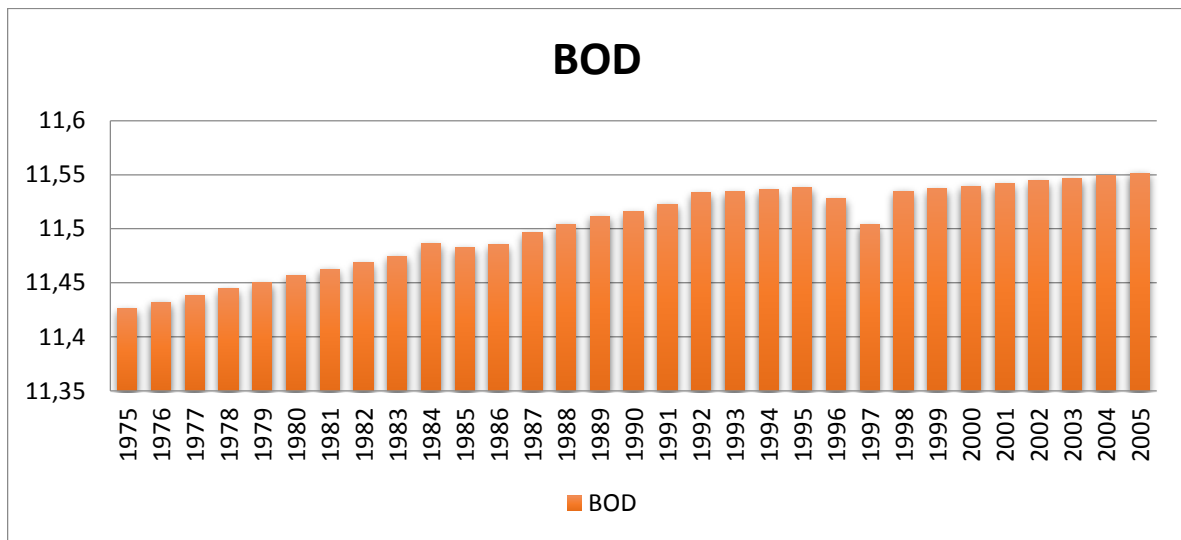
Figure (3.15): The Yearly Biological Oxygen Demand (BOD) Discharge per worker

Source: Compiled by the Researcher based on the World Bank Database

➢ **Pollution of Rivers**

The domestic industrial sewage is thrown in a raw status into the water bodies causing pollution, the fact which led to a very dangerous condition for water resources and public health. Since 1985, the observation network for water quality development was enlarged to

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[1] National report about the environmental status, The Algerian Ministry of Environment and Land Use Planning, 58.

nearly 120 sampling stations located along the major watercourses and dams. Samples are collected monthly and analyses involve 30 parameters to measure the water quality. According to the Human Development Report[1] for 2011, the number of deaths caused by water contamination was estimated at 247 for every 1 million inhabitants in 2004.

The western region contains an important portion of rivers such as Tafna, Cheliff, Mina, Mouilah, Sarnoand, Saoura and Mebtoul. These rivers are affected by some pollution. While in the central and Eastern regions, El Harrach River is totally polluted, Mazafran River, Rhummel River, Kebir West River and Seybouse River, are significantly polluted rivers. The following table shows BOD and COD levels in rivers as follows:

Table (3. 5) Pollution Burden on Rivers

BOD (Tonnes/year)	COD (Tonnes/year)	AZOTE Tot.(Tonnes/year)	Phosphor Tot.(Tonnes/year)
96.838	376.326	30.041	9.903

Source: Report on the State of the Environment 2007, p110.

The rivers in Algeria suffer a lot from pollution because of the limited quantity of water in these water bodies. This makes the concentration of the BOD and COD and other pollutants high. The freshwater in Algeria has a medium quality and generally it is allowed to use for different usages, however because of arid climate in some parts of the highlands, groundwater salinity may limit the inhabitants' use of these waters. In the Sahara, although it varies depending on the area, the salinity of the groundwater is much greater 2 g / L, and it

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[1] United nation Human development report for 2011, accessed September 29th , 2015, http://hdr.undp.org/en/media/HDR_2011_AR_Chapter2.pdf

greatly reduces the possibilities of usage of these waters[1]. The government is actively rearranging the water sector and grouping waters. Potable water is monitored daily by the health services and hygiene community offices. Testing for residual, chlorine is used as an indicator of bacteriological contamination (higher chlorine levels indicate higher contamination).

3.2.2.3.   Solid Waste, Land Degradation and Biodiversity in Algeria

➢   **Solid Waste**

In Algeria the solid waste production is increased due to several factors, such as the demographic growth, the increasing of urbanization, and the socio-economic changes in the country. All these have been accompanied by significant changes in the consumption pattern which has led to huge changes in the quantity and quality of the generated solid wastes.

01-19 law issued in 12 December 2001[2] related to management, control and disposal of waste, defined the general framework about the control and disposal of waste, and dedicated a rational management, which included collection, transport, sorting, recovery and processing of solid wastes. According to this law the solid wastes are divided into three categories[3]:

✓   Household wastes, as well as similar waste from industrial and commercial activities.

✓   Special wastes including hazardous usages and wastes.

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[1] National report about the environmental status, The Algerian Ministry of Environment and Land Use Planning, 58.

[2] Algerian Official Journal, number 01, Executive Decree n ° 01-19, 12 December 2001.

[3] National Office of Statistics, "2015 Environmental Statistics Report", 67.

✓   Bulky wastes.

Table (3. 6): Evolution of Household Waste Production

	1977	1987	1998	2008
Population	16948000	23039000	29081000	34080000
Quantity of generated household waste (tonne)	3093	4200	5300	8700

Source: National Office of Statistics, "2015 Environmental Statistics Report", 67.

Through the table above, we note that the population growth in the period of 1998 to 2008, was 17.18%, while the growth rate of generated wastes by households was 64.15%, the fact which showed a large growth of the generated wastes by population. This is due to the consumption pattern which did not take in consideration the environmental side.

➢   **Land Degradation**

Land degradation in Algeria is caused by many factors such as multiple usage of land, drifting, mining, pressure of agriculture production (fertilizer)…etc. The Forestry Administration in Algeria estimated the erosion-prone area to be about 12 million Hectares, in the mountainous regions in the northern part of the country, and 20 million Hectares in Steppes areas. The yearly losses of agricultural lands is estimated to be around 40000 Hectares [1]. This is due to the lack of vegetation, overgrazing and bad distribution of population,

A study carried out by the General Administration of Forests on 34 basins out of the 52 existing at the national level, showed that 13 million hectares are threatened by water

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[1] Tolmattin Abla, "The impact of climatic changes on the economic growth in Algeria, analytic and empirical study during the period 1980-2009", 110.

erosion. From 238 million hectares of land in Algeria, 200 million are located in the Saharan zone, 20 million hectares in the savannah zone, with very fragile soils subjected to the desertification process, and the remainder of 18 million hectares consists of mountains, plains and hills. The provinces threatened by desertification are nine (Djelfa, M'Sila, Naama, El Bayadh, Biskra, Khenchela, Batna, Tébessa and Laghouat)[1]. There are three new provinces concerned with this phenomenon, which are Tlemcen, Tiaret and Saïda.
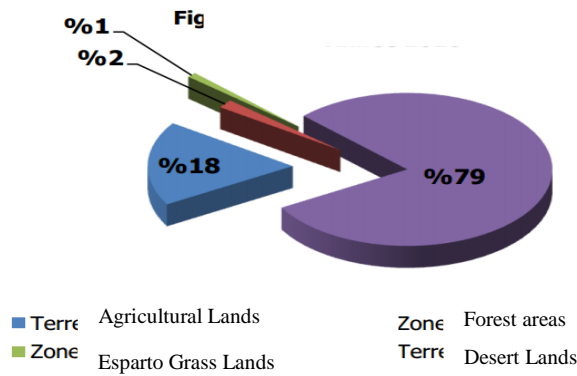
Figure (3-16): Land Distribution in 2010

Source: National Office of Statistics, "2015 Environmental Statistics Report", 36.

➢ **Biodiversity**

Algeria is a Mediterranean country and it is one of the richest countries in biodiversity. This is mainly due to the strategic location, diversity of its climate and topography. According to the ministry of territorial and environmental statistics, there exists more than 5000 kinds of animals and 3139 kind of plants in Algeria[2]. This diversification

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[1] National report about the environmental status, The Algerian Ministry of Environment and Land Use Planning, 58.
[2] Tolmattin Abla, "The impact of climatic changes on the economic growth in Algeria, analytic and empirical study during the period 1980-2009", 110.

from north to south is related to the multiplicity of ecosystems (coastal ecosystem, forestry ecosystem, mountainous ecosystem, desert ecosystem). Indeed, these ecosystems face many factors which may cause elimination of rare species, such as overgrazing, drifting, drought, loggers, forests burning, desertification, in addition to the problem of coastal pollution. Although biodiversity in Algeria is too rich, because of these factors and others, biodiversity remains in continuous decline. The United Nation 2011 Human Development Report estimated that the rate of endangered species in Algeria is about 13% of the total kinds.

3.3.   The Local Environmental Laws in Algeria

Just as many other countries, Algeria is suffering from various environmental problems such as: air pollution, water pollution, Land degradation…etc.

3.3.1.   The Evolution of Environmental Institutions and Environmental Laws in Algeria

The Algerian environmental institutional system and legislation frame knew several developments, after the independence. Algeria's focus was to rebuild the country after the exploitative French colonialism[1] and so, it neglected the environmental side to a far extent. Algeria tried to draw lines in order to protect the environment, and even if they were a few, they gradually started issuing environmental laws and regulations. Algerian authorities established the National Environment Council in 1974 as a consultation body that gives suggestions in the environment conservation field. In 1983, the environment conservation law was issued, bearing general principles of different environmental conservation sides.

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[1] Mohamed Zidan, Faraj Shaaban, "Preservation of the environment as an entry point to sustainable development," The National Forum on economy sustainable development, (2006), Chlef University.

This law is considered as a legal rebirth in order to protect the environment from attrition. The same law also opened a wide scope to give importance to the environment, which led to many regulations and laws-issuing.

Table (3. 7): Developments of Environmental Institutions Establishment in Algeria

Year	The Institution
1974	National Council of Environment.
1977	Council Dissolved and its duties transferred to the Ministry of Irrigation and Land Reclamation And Environmental Protection, and the establishment of the Directorate of the Environment.
1981	Name of the Directorate of Environment changed to the Directorate of Nature Conservation and Upgrading.
1983	Establishing the National Agency for Environmental Protection (NAEP).
1984	Assignment the environment duties to the Ministry of Environment and Forests.
1988	Shifting the duties of environment to the Ministry of Agriculture.
1990-1992	Shifting the duties of environment to secretary of state scientific research at the Ministry of higher education and scientific research.
1996	The environment sector appended to the Ministry of the Interior and community groups, (i) Establishment of the Directorate General for the Environment, and the General Inspectorate of Environment, (ii) The establishment of the highest Council for the Environment and Sustainable Development.
1996-2003	Establishing the Ministry of Environment and Land Use Planning (MELUP), the establishment of environmental inspectorates in 48 state, and environmental directorates in Different cities.

Source: Bernie Latifa, "Environmental management role in creating a competitive advantage for industrial enterprise"[1], 34.

   The shift of the different ministerial sectors in the environmental field during three decades after independence led to the instability in environment management and to imprecise activity consequences. This worsened the urban and industrial pollution besides

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[1] Bernie Latifa. "Environmental management role in creating a competitive advantage for industrial enterprise case study (EN.I.CA.BISKRA)", (Master dissertation ,University Mohamed El Khider ,Biskra ,Algeria, 2007),34 .

speeding up natural environment deterioration. Environmental policy continued to face problems due to the fact that several civil servants in charge of environmental issues suffered a lack of proper training and due to the presence of conflicting competences between several ministries. Given these shortcomings, the existing legislation could and still can easily be ignored. The environmental policy often continues to be conceived within the framework of infrastructure investment, as when it comes to questions of water treatment, waste disposal or the mobilization of water resources via the construction of dams; or the framework of regional development (with regard to the southern Saharan regions) or as part of agricultural development[1]. In this manner, environmental concerns are often intermingled with growth considerations or linked to proclaimed political goals such as self-sufficiency, regional development or job creation.

- **Environmental Protection in the Frame of Sustainable Development Law**

Sustainable development law was signed on July 2003, in which the Algerian legislator adopted the outlines of sustainable development principals for Rio de Janeiro Summit in 1992, wherein the most important addressed points are[2]:

✓ Controlling different environment compositions by putting borders in the form of critical thresholds for pollution levels

✓ The necessity of environment exploiter nomination, with ensuring the self-control and supervision application.

[1] BTI , "Algeria Country Report", This report is part of the Bertelsmann Stiftung's Transformation Index, accessed Jun 27th ,2015, http://www.btiproject.de/fileadmin/Inhalte/reports/2012/pdf/BTI%202012%20Algeria.pdf
[2] Nacira Quraish, Medioni Djamila, "The Legal Procedures to Protect the Environment", the National Forum on Environment and the Economy and Sustainable Development", University Medea 06-07 June, 2006, 15.

✓   Generalizing the environment integration into all educational levels.

✓   Encouraging and motivating importing the tools and equipment which help reduce pollution through reducing the tariffs.

3.3.2. Environmental Taxation in Algeria

The first environmental tax was introduced through the Finance Code of 1992, in which it levied Taxes on Polluting and Dangerous Activities (TPDA), but the implementation of this law started only after renewing and restructuring a number of fiscal arrangements through the finance code of 2000-2003. The earnings obtained from environmental taxes address different part: 75% from its revenues go to the national fund of environment and finance pollution reduction, the rest of the earnings include 10% that go to municipal budget and 15% to the public budget.

- **Solid Waste Taxes**

a)   Motivational Tax for No Storage of Medical Wastes: The tax amount is estimated by virtue of the Finance Code of the year of 2002 at 24000 DZD for one ton of medical wastes. This tax came because of the enormous quantities of medical wastes which are improperly burnt to reduce costs. The total tax is allocated as follow: 10% goes for municipal budget, 15% goes for public budget and 75% for the National Fund of Environment and Decontamination organization.

b)   Motivational Tax for Non-Stocking of Particular Industrial Wastes: This tax was introduced by virtue of the rule number 203 of Finance Code of 2002[1], in order to motivate the industrial companies of the no-storage of particular industrial wastes and dangerous

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[1] Algerian Official Journal, number 01-19, "Law on conducting, monitoring, and removing wastes", 15 December 2001.

wastes since stoking this kind of waste is polluting the environment. Its amount was determined by 10500 DZD for every ton of these wastes. The earnings of this tax are allocated as follows: 10% for municipality, 15% for public budget and 75% for the National Fund of Environment and Decontamination. The exploiter takes a period of 3 years starting from the tax passing date to initialize the necessary waste disposal equipment.

c)   **Tax on Plastic Bags:** This tax was introduced by virtue of Finance Code of 2004. It includes all the plastic bags, either locally manufactured or imported. The tax is estimated at the amount of 10.5 DZD/Kg, and the earnings go to the National Fund of Environment and Pollution Decontamination.

➢   **Tax on Polluting and Dangerous Activities (TPDA)**

This Tax was introduced in the Finance Code of 1992 and was levied on classified institutions which may cause dangers and nuisances or harm to the public health, hygiene, security, nature, environment, monuments as well as the touristic areas[1].

•   **Air Pollution Emissions Taxes:** This tax was introduced by virtue of the Finance Code of 2002. It contains two kinds:

a)   **Air Pollution Complementary Tax**: This tax related to the industrial activities whose emissions exceed the maximum limits identified by the law. The tax amount is calculated by virtue of (TPDA) level, in addition to the using of multiplier coefficient from 1 to 5, which reflects how much the maximum limits are exceeded from the levels determined in the regulations. The revenues of this tax are allocated as follows: 10% for the municipality,

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[1] Nacira Quraish, Medioni Djamila, "The Legal Procedures to Protect the Environment", the National Forum on Environment and the Economy and Sustainable Development", University Medea 06-07 June, 2006, 16.

15% for the public budget and 75% for the National Fund of Environment and Decontamination.

b)   **Fuel Tax:** This tax is estimated at the amount of 1 DZD for every liter of fuel (It contains both ordinary and super), and the tax amount is equally divided between the National Fund of Environment and Decontamination and the Roads and Freeways National Fund.

•   **The Complementary Tax for Wastewater from Industrial Sources:** The tax is calculated in the same way as the air pollution complementary tax. The earnings of this tax are allocated as follows: 30% for the municipality, 20% for the public budget and 50% for the National Fund of Environment and Decontamination.

3.3.3.   International Environmental Conventions and Agreements Approved by Algeria

Algeria seeks through its policy to conserve the environment. Whereas it is one of the active countries in the United Nations in environment conservation program also it is a partner in Euro-Mediterranean conventions, Arabic, African and international agreements. Some of these agreements can be summarized in the following table.

Table (3.8) International Environment Conventions and Agreements Signed by Algeria

Convention	Date of membership Ratification	The Obligation of Reporting
United Nations Framework Convention on Climate Change UNFCCC	Ratified in 1993 and came into force in 1994	1st National Communication (NC): April 30, 2001 2 (NC) inventory greenhouse gas in 25 November 2010 2nd 2011 communication in editing phase.
Kyoto protocol	Ratified in 2005 and came into force in 2005	The process of "developing National Climate Plan" is ongoing through 09 regional workshops.
United Nations Convention on Fight against Desertification	Signed in 1992. Ratified in 1996	National Report 3 reports (1999, 2002, 2004).
United Nations Convention on Biological Diversity	Signed in 1992 took part since 1995	National Report: 1997, 2005 The fourth report is sent to the secretariat of the Convention.
Cartagena Protocol	Took part since 2004	Information is not available.
Vienna Convention	1992	
Montreal Protocol	1992	
The Convention on Wetlands of International Importance, especially as Waterfowl Habitat Ramsar	Came into force 1984	Low Nr 11-02 February 17, 2011.
Bonn Convention (migratory species, land, sea and air)	Came into force 2005	

The Convention on International Trade in Endangered Species of Wild Fauna and Flora	Came into force 1984	Report 2002, 2003, 2004, 2005, 2006, 2007.
Basel Convention	Membership in 1998, joining after the amendment of the Convention in 2006	Reports: 2006, 2005, 2004, 2002, 2001, 2000. As part of its implementation, there is a satisfaction with the obligations relating to the provisions of Articles 13 and 16 of the Convention (data updated by the country / since 2003).
Barcelona Convention on Persistent Organic Pollutants	Signed in 2001 .Ratified in 2006	The national plan for the implementation of this agreement has been developed in collaboration with the sectors concerned with including: completion of the inventory of Pop's (PCBs, Pesticides, Dioxins and Furans, Contaminated Sites) and evaluation of infrastructure and national capacity.
United Nations Convention on the Law of the Sea	Ratified in 1996	
Barcelona Convention	Ratified in 1981	For its implementation and in terms of data: National Diagnostic Assessment (BDN), the National Assessment of Base emissions by rejection (BBN),

		the National Action Plan (NAP) have been developed to update the (BBN).
Convention related to Wetlands	11 December 1982	Law 11-02 of 17 February 2011.
The Convention on International Trade in Endangered Species of Wild Fauna and Flora	1982	
African Convention on the nature of Natural Resources (Algiers)	1982	
Protocol on Specially Protected Areas and Biological Diversity in the Mediterranean	1995	Law 11-02 of 17 February 2011.

Source: Algeria Country Report, Algerian Ministry of Environment and Land Use Planning (MELUP), national observatory of environment and sustainable development, (2012), 25.

It is obvious from the table that Algeria has participated in many conventions and issued many environmental laws, but that does not necessarily mean that the environment is indeed protected, neither does it say that the laws are well managed or imposed. The environment in Algeria cannot be protected by simply placing obstacles on industrial plants, rather, these are supposed to be encouraged or obliged to be built applying standards of green architecture, and in addition, there should be production concerning the field of environment through greening the cities and providing industrial artificial lakes, green spaces…etc.

Chapter Conclusion

Throughout this chapter, we conclude the following results: the first point is that Algeria has gone through the phase of planned economy, which has resulted in huge investment programs that have changed many of the criteria related to poverty, ignorance and illiteracy. The second point is that concerning its structure, the Algerian economy is only based on one pillar, which is the hydrocarbon sector. This fact has made the Algerian economy limited to all worldwide changes in the oil market, as the oil crisis that Algeria has witnessed in 1986, and even now, Algeria is going through a similar case because of the degradation of the oil prices in the oil market, the fact that influenced the development and economic activities in Algeria. The third point is that, through following the development agenda in Algeria, the lack of the consideration and appreciation of the environment in development programs became clear, especially in the first phases after independence. Algeria suffers numerous environmental problems, such as the air pollution, water pollution, desertification, the overuse of the oil resources…etc. and these are mainly caused by the overpopulation, development policies, the production and consumptions patterns…etc.

Chapter Four

Chapter Introduction

In this chapter, we will introduce the classical sets and fuzzy sets and their main operations and properties. Then, we will demonstrate the traditional regression by illustrating the Ordinary Least Square Method as well as the fuzzy regression methods, the linear programming estimation method of Tanaka and fuzzy least square regression method FLSR. All this will introduce us to estimate the environmental Kuznets Curve in the case of Algeria, which examines the impact of the economic growth on the environment in Algeria.

4.1. The Classical (Crisp) Sets and Fuzzy Sets

In this section, the theory on classical (crisp) sets and the basic ideas of fuzzy sets are discussed. The various laws, properties and operations of Classical sets are introduced along with those of the Fuzzy sets.

4.1.1. Crisp Sets and the Operations on Them

The theory of the classical set is built on the fundamental concept of "set" of which an element is either a member or not a member. A crisp, sharp and unambiguous distinction exists between a member and a nonmember for any well-defined "set" of entities in this theory, and there is a very clear and precise boundary to indicate if an element belongs to the set. That is to say, when the question "Is this element a member of that set?" is asked, the answer must be "yes" or "no." In this part the classical sets fundamental, properties and relations are discussed.

4.1.1.1. Fundamental Concepts about Classical Sets

If **A** is a nonempty set, called the universe set below and consisting of all the possible elements concerned with a particular context. Each of these elements is called a member, or an element of **A**. A union of several (finite or infinite) members of **A** is called a sub set of **A**[1]. Sets are denoted in this text by upper-case letters and their members by lower-case letters for example x is an element or a member of the set **A**. To indicate that x, an element of the set **A** belongs to **A**, we write

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[1] Chen Guanrong, Trung Tat Pham, *Introduction to fuzzy sets, fuzzy logic, and fuzzy control systems* (USA: CRC Press LLC, 2001), 1.

$$x \in A \tag{4.1}$$

If x is not a member of A, we write

$$x \notin A \tag{4.2}$$

There are three basic methods by which sets can be defined within a given universal set X:

1.   A set is defined by naming all its members (the list method): This technique can be used only for finite sets. The set A, whose members are a_1, a_2, ..., a_n, is usually written as

$$A = \{a_l, a_2, ..., a_n\} \tag{4.3}$$

2.   A set is defined by a property within by its members (the rule method). A common notation expressing this method is

$$A = \{x \mid P(x)\} \tag{4.4}$$

Where the symbol | denotes the phrase "such that (so that, of a kind, of this kind)", and $P(x)$ designates a proposition of the form x that has the property P[1]. That is, **A** is defined by this notation as the set of all elements of X for which the proposition P(x) is true. It is required that the property P be such that for any given $x \in X$, the proposition (x) is either true or false.

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[1] Georgr J. Klir, Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications* (USA: Prentice-Hall Inc, 1995), 6.

3.   A set is defined by function, usually called characteristic function, that declares which elements of X are members of the set and which are not. Set **A** is defined by its characteristic function x_A as follows:

$$x_A^{(x)} = \begin{cases} 1 & x \in A \\ 0 & x \notin A \end{cases}$$

(4.5)

That is, the characteristic function maps the elements of X to the elements the set {0, 1}, which is formally expressed by

$$x_A: X \longrightarrow \{0,1\}$$

(4.6)

For each $x \in X$, when $x_A^{(x)} = 1$, x is declared to be a member of **A**, whereas when $x_A^{(x)} = 0$, x is declared as a nonmember of **A**.

The operation of mapping a set of theoretic form to function as a theoretic form is an important concept. For example, if X and Y were two different universe sets where an element x is contained in **X** but simultaneously relates to an element y contained in **Y**[1], the equation will normally be presented as

$$f: X \rightarrow Y$$

(4.7)

This is termed as the mapping form from X to Y. The characteristic function χ_A is defined in the former equation (4.5). Therein, χ_A represents the membership of the elements x in the universe within the set A. As for the membership mapping of the crisp set **A**, it is illustrated in the following figure,

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[1] S. N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, (Berlin: Springer, 2007), 16, 17.
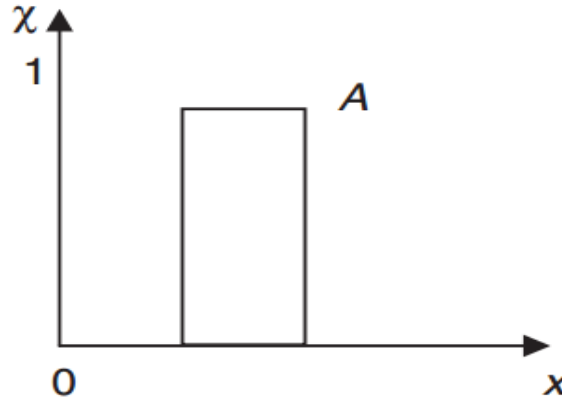
Figure (4.1): Membership Mapping for Crisp Set A

Source: S. N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, (Berlin: Springer, 2007), 16.

In the table below the main operations on the set function forms are as follow:

Table (4.1): Operations on the set function form

Union:	Intersection:
$A\cup B \rightarrow \chi_{A\cup B}(x) = \chi_A(x) \vee \chi_B(x)$ $= \max(\chi_A(x), \chi_B(x))$. Here $\vee$ indicates the maximum operator	$A\cap B \rightarrow \chi_{A\cap B}(x) = \chi_A(x) \wedge \chi_B(x)$ $= \min(\chi_A(x), \chi_B(x))$. Here $\wedge$ indicates the minimum operator.
Complement: $\overline{A} \rightarrow X_{\overline{A}}\ (x)\ =\ 1- \chi_A(x).$	**Containment:** $A\subseteq B \rightarrow \chi A(x) \leq \chi B(x)$

Source: summarized by the Author based on N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 16

> ➢ A set whose elements are themselves sets is often referred to as a family of sets. It can be defined in the form

$$A = \{A_i \mid i \in I\} \tag{4.8}$$

Where i and I are called the set index and the index set, respectively because the set index i is used to reference the sets A_i. The family set is also called an indexed set[1]. Here families of sets are usually denoted by script capital letters. For example:

$$A = \{A_1, A_2, \ldots, A_n\} \tag{4.9}$$

➤ if every member of set **A** is also a member of set **B** (i.e., if $x \in A$ implies $x \in B$), then **A** is called a subset of **B**, and this is written as

$$A \subseteq B \tag{4.10}$$

➤ Every set is a subset of itself, and every set is a subset of the universal set. If $A \subseteq B$ and $B \subseteq A$, the A and B contain the same members. They are then called equal sets; this is denoted by

$$A = B \tag{4.11}$$

To indicate that A and B are not equal, it is written

$$A \neq B \tag{4.12}$$

➤ If both $A \subseteq B$ and $A \neq B$, then **B** contains at least one individual that is not a member of **A**. In this case, **A** is called a proper subset of **B**, which is denoted by

$$A \subset B \tag{4.13}$$

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[1] Georgr J. Klir, Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications,* 7.

When $A \subseteq B$, it is said that A is included in B.

➢ The family of all subsets of a given set A is called the power set of **A**, and it is usually denoted by $\mathcal{P}$ (A). The family of all subsets of $\mathcal{P}$ (A) is called a second order power set of **A**; it is denoted by $\mathcal{P}^2$(A), which stands for $\mathcal{P}$ ($\mathcal{P}$ (A). Similarly, higher order power sets $\mathcal{P}^3$(A), $\mathcal{P}^4$(A)… can be defined.

The number of members of a finite set A is called the cardinality of **A** and is denoted by |**A**|. When **A** is finite, then

$$| \mathcal{P} (A) | = 2^{|A|}, | \mathcal{P}^2(A) | = 2^{2^{|A|}}, \text{ etc.} \tag{4.14}$$

➢ The relative complement of a set **A** with respect to set B is the set containing all the members of B that are not also members of $\mathbf{A}^1$. This can be written $B - \mathbf{A}$. Thus,

$$B - A = \{x | x \in B \text{ and } x \notin A\}. \tag{4.15}$$

➢ If the set B is the universal set, the complement is absolute and is usually denoted by $\overline{A}$. The absolute complement is always involutive; that is taking the complement of a complement yields the original set, or

$$\overline{\overline{A}} = A \tag{4.16}$$

➢ The absolute complement of the empty set equals the universal set, and the absolute complement of the universal set equals the empty set. That is,

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[1] Ibid., 7.

$$\overline{\varnothing} = X \tag{4.17}$$

In addition to

$$\overline{X} = \varnothing \tag{4.18}$$

4.1.1.2.   Operations on Classical Sets

There are numerous operations that can be accomplished in the crisp or classical sets. The outcomes of the processes executed on the classical sets are definite. The operations that can be done on the classical sets are tackled in details as follows[1]:

For example, if we consider that two sets, *A* and *B*, are defined on a universe called **X**, it is these two sets, **A** and **B** that define the operations of classical sets, because these operations are based on them.

✓   **Union**

$A \cup B$ denote the union of the two classical sets *A* and *B*. $A \cup B$ represents all the elements in the universe that correspond to either the set *A*, *B* or both. This process is termed the logical OR.

In this set, the theoretic form is represented as

$$A \cup B = \{x / x \in A \text{ or } x \in B\} \tag{4.19}$$

Venn diagram represents the form as illustrated in the following figure:

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[1] S. N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, (Berlin: Springer, 2007), 13.
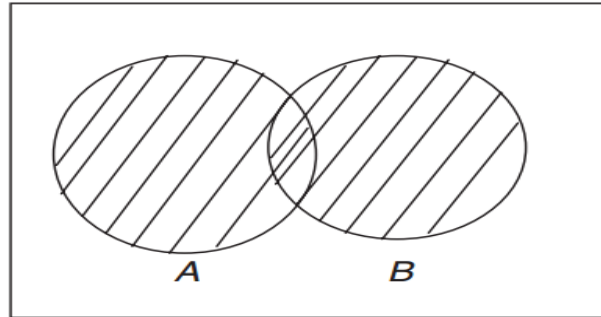
Figure (4.2):   Union A∪B

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 13.

✓   **Intersection**

$A∩B$ is the intersection of the two sets A and B and it represents all those elements that belong to the universe X and simultaneously correspond to (or belongs to) both sets A and B[1]. In this set, the theoretic form it is represented as

$$A∩B=\{x/x\in A \text{ and } x\in B\} \tag{4.20}$$

In Venn diagram form it can be represented as shown below:
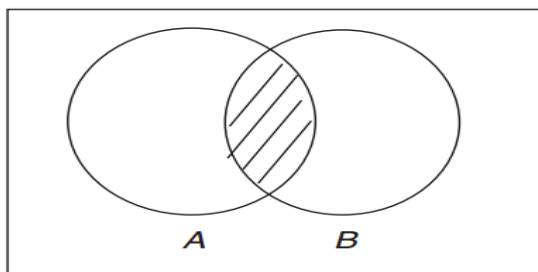
Figure (4.3): Intersection **A∩B**

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 13.

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[1] Ibid., 14.

   ✓   **Complement**

The complement of the set A indicates A, and is defined as the collection of all the elements in the universe that do not correspond to the set A. In this set, the theoretic form is represented as:

$$A=\{x/x \notin A, x \in X\} \tag{4.21}$$

In Venn diagram form, it is represented as shown in the following figure:
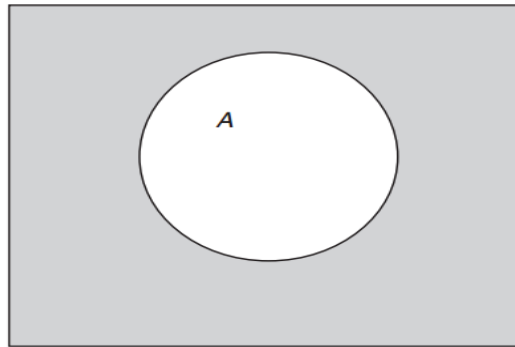
Figure (4.4): Complement of set *A*

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 14.

   ➢   **Difference**

The difference of a set *A* with respect to *B*, indicated *A* | *B* is defined as a collection of all the elements in the universe that correspond to *A* and do not simultaneously correspond to *B*[1]. In this set, the theoretic form it is represented as

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[1] Ibid., 14.

$$A|B=\{x/x\in A \text{ and } x \notin B\} \tag{4.22}$$

In Venn diagram form, it is represented as shown below.
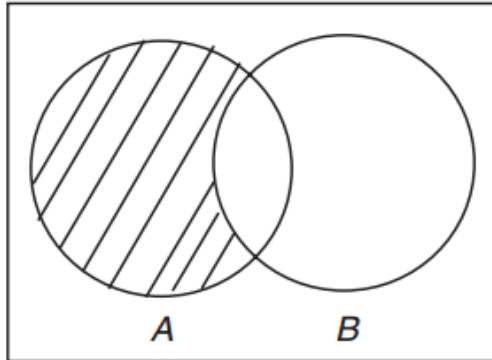
Figure (4.5): Difference A|B

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 14.

4.1.1.3.   Properties of Classical Sets

The properties play a major role in any mathematical operations, and the solution can be extracted for the problems based upon them. The following are the significant properties of classical sets[1]:

✓   **Commutativity**

$$A\cup B=B\cup A, \tag{4.23}$$

$$A\cap B=B\cap A. \tag{4.24}$$

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[1] Ibid., 15.

✓ **Associativity**

$$A \cup (B \cup C) = (A \cup B) \cup C, \qquad (4.25)$$

$$A \cap (B \cap C) = (A \cap B) \cap C. \qquad (4.26)$$

✓ **Distributivity**

$$A \cup (B \cap C) = (A \cup B) \cap (A \cup C), \qquad (4.27)$$

$$A \cap (B \cup C) = A \cap B) \cup (A \cap C). \qquad (4.28)$$

✓ **Idempotency**

$$A \cup A = A, \qquad (4.29)$$

$$A \cap A = A. \qquad (4.30)$$

✓ **Identity**

$$A \cup \varphi = A \qquad (4.31)$$

$$A \cap X = A \qquad (4.32)$$

$$A \cap \varphi = \varphi \qquad (4.33)$$

$$A \cup X = X. \qquad (4.34)$$

✓ **Transitivity**

$$\text{If } A \subseteq B \subseteq C, \text{ then } A \subseteq C. \qquad (4.35)$$

In this case the symbol ⊆ means "contained in" or "equivalent to" and ⊂ means "contained in"[1].

✓ **Involution**

$$A = A. \tag{4.36}$$

There are two other important special properties that include De Morgan's law and the excluded middle laws.

✓ **Excluded middle law**

It contains both the law of contradiction and the excluded middle law. The latter is very important because its laws are the only set operations that are not valid, neither for classical nor for fuzzy sets. The law of the excluded middle represents a union of a set A and its complement.

$$A \cup \overline{A} = X \tag{4.37}$$

The law of contradiction represents the intersection of a set A and its complement

$$A \cap \overline{A} = \Phi \tag{4.38}$$

✓ **De Morgan's Law**

These are highly significant because they are effective in proving the tautologies and contradictions in logic. The De Morgan's law is given as[2]

$$A \cup B = A \cup B, \tag{4.39}$$

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[1] Ibid., 15.
[2] Ibid., 16.

$$A \cap B = A \cap B. \hspace{3cm} (4.40)$$

In Venn diagram form it is represented as shown below:

$$A \cap B \hspace{5cm} A \cup B$$
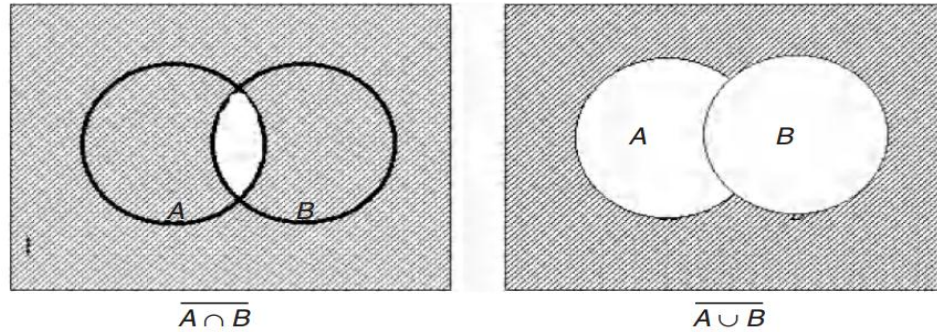
Figure (4.6): De Morgan's law.

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 16.

The complement of a union or an intersection of two sets equals the intersection or union of the respective complements of those two sets. This statement is made for the De Morgan's law.

4.1.2.   Fuzzy Sets and the Operations on Them

In order to differentiate between the members and nonmembers of the classical sets, the characteristic function assigns a value of either 1 or 0 to each element in the universal set, while the concept of fuzzy sets is based on containing elements that have varying degrees of membership in the set. In this section some concepts, operations and characteristics about the fuzzy set will be presented, and before that a brief introduction will be addressed about fuzzy logic.

4.1.2.1.   Fundamental Concepts about Fuzzy Logic and Fuzzy Sets

In this section the concept of fuzzy logic a new thinking perspective will be introduced as well as the definition of the fuzzy sets.

➢   **The Concept of Fuzzy Logic**

Fuzzy logic is a scientific discipline that was established by Lotfi Zadeh (1973, 1975, 1976, 1978 and 1983). Fuzzy logic is not a unique system of knowledge, instead, it is a variety of methodologies proposing a logical consideration of imperfect and vague knowledge. It is an active area of research with some topics still under discussion and debate. Fuzzy sets are a generalization of classical sets and infinite-valued logic is a generalization of classical logic. Fuzzy logic is used as a major tool—fuzzy set theory. Basic mathematical ideas for fuzzy logic evolve from the infinite-valued logic, thus there is a link between both kinds of logic. Fuzzy logic can be considered as an extension of infinite-valued logic in the sense of incorporating fuzzy sets and fuzzy relations into the system of infinite-valued logic[1].

The fuzzy sets theory is also used in the field of economics. Ponsard and Fustier (1986) edited the first main book that was dedicated to the applications of fuzzy set theory in economics. Ponsard's ground-breaking contributions to fuzzy economics were this book together with two other papers (1981, 1988) that cover sufficient information about fuzzy logic. Later, Butnariu (1978, 1985) presented the concept of a fuzzy game[2]. In recent days

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[1] George Bojadziev, Maria Bojadziev S., *Fuzzy logic for Business, finance and Management*, 2nd edition (Singapore: World Scientific Publishing, 2007), 43.

[2] Georgr J. Klir, Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications,* 450.

various studies in the economic domain have been appeared using the fuzzy logic in estimating the economic relationships in the uncertainty conditions of the world economy.

Fuzzy logic focuses on linguistic variables in natural language, and aims to provide foundations for approximate reasoning with imprecise propositions. It reflects both the rightness and vagueness of natural language in common-sense reasoning.

The relations between classical sets, classical logic, fuzzy sets (in particular fuzzy numbers), infinite-valued logic and fuzzy logic are schematically illustrated in Fig (4.5).

Major parts of fuzzy logic deal with linguistic variables, linguistic modifiers, propositional fuzzy logic, inferential rules and approximate reasoning.
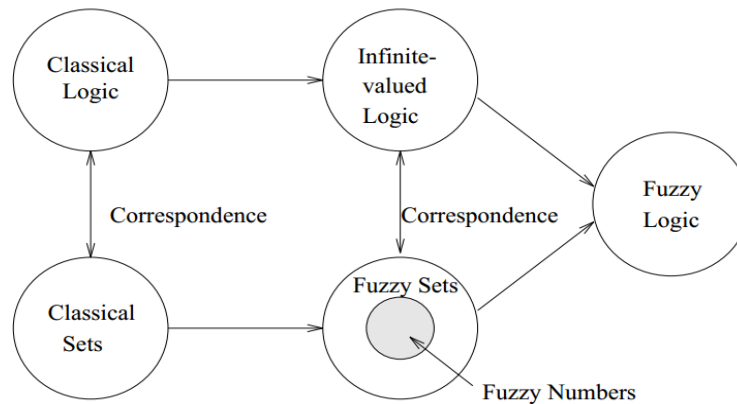
Figure (4.7): Evolvement of Fuzzy Logic

Source: George Bojadziev, Maria Bojadziev S., *Fuzzy logic for Business, finance and Management*, 44.

➢   **The Concept of Fuzzy Sets**

If a given fuzzy set $\tilde{A}$ is defined on a universal set **U**, then in the set of all elements of **U**, $\tilde{A}$ (x) >0 is called a support of $\tilde{A}$, and the set of those for which $\tilde{A}$ (x) =1 is called a core of $\tilde{A}$. When the cores of fuzzy sets are not empty, these are called normal fuzzy sets, but all other fuzzy sets are subnormal. Amongst the most important concepts related to fuzzy sets, there is the concept of a level cut (also called an α-cut). Given a fuzzy set $\tilde{A}$ defined on a universal set U and any number α in the interval [0,1], the level cut at the level α (or α -cut) of $\tilde{A}$, which is denoted by $\tilde{A}_\alpha{}^1$, is a classical set of all objects x of **U** for which $\tilde{A}$ (x) ≥ α . This is formally written in the form

$$\tilde{A}_a = \{x \in U \mid A(x) \geq a\} \qquad (4.41)$$

Where the standard symbol $x \in$ U denotes that a given object x is a member of the universal set U (a classical set). From this definition, it immediately follows that for any fuzzy set $\tilde{A}$ and any two numbers α and β in [0, 1] such as α > β, the set inclusion $\tilde{A}_\alpha \subseteq A_\beta$ always holds. That is, all distinct level cuts of any fuzzy set $\tilde{A}$ form a family in the form

$$\tilde{A} = \{ \tilde{A}_\alpha \mid \alpha \in [0, 1]\} \qquad (4.42)$$

That is a form of nested classical sets, which signifies that for any sequence of numbers $\alpha_1 > \alpha_2 > \alpha_3 > \cdots$ in [0, 1], $A\alpha 1 \subseteq A_{\alpha 2} \subseteq A_{\alpha 3} \subseteq \cdots$. It has been mathematically established that this family is an alternative representation of fuzzy set v (Klir and Yuan 1995).

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[1] N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 19.

Given the level-cut representation of fuzzy set $\tilde{A}$, its membership-function representation is uniquely determined for all x $\in$ U by the formula

$$\tilde{A}\ (x) = \sup\ \{\alpha | \alpha \in [0,\ 1],\ x \in A\alpha\} \qquad\qquad (4.43)$$

Where "sup" denotes supremum (or maximum, if it exists).

A fuzzy number is defined on the universe R as a convex and normalized fuzzy set. The interval $[\alpha_1,\ \alpha_2]$ is called supporting interval for the fuzzy number. The fuzzy set is mapped to a real numbered value in the interval 0 to 1[1].

• **Membership Function**

Membership functions are the features responsible for illustrating the quality of fuzziness inside a fuzzy set. Be it continuous or discrete, the membership functions' role is to classify the elements in the fuzzy set. Membership functions can be graphed in diverse figures, and they are discussed in the following section:

▪ **Features of Membership Function**

The membership function feature is determined by three characteristics. These proprieties are:

(1) **C**ore   (2) **S**upport   (3) **B**oundary

The membership degree takes value between 0 and 1. The following figure presents the feature of membership function.

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[1] Ibid., 20.
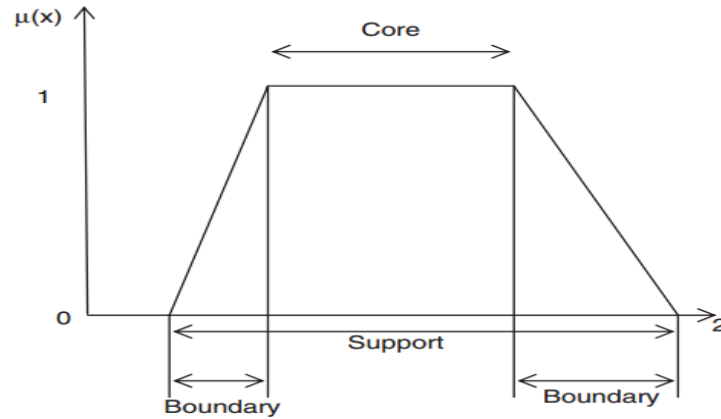
Figure (4.8): Membership Function Features

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 74.

(1) **Core**

The elements, that have a full membership function as 1 are the components of the core, i.e., here $\mu_{\tilde{A}}(x) = 1.$[1]

(2) **Support**

The membership function support of a fuzzy set $\tilde{A}$ is the universe area, which is characterized by nonzero membership in the set $\tilde{A}$, the support contains the elements whose membership is more than 0. $\mu_{\tilde{A}}(x) \succ 0$.

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[1] N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 74.

(3) Boundary

In case the region of universe contains neither a nonzero membership nor full membership, this describes the boundary of a membership function for a fuzzy set $\tilde{A}$. The boundary contains the components whose membership is among 0 and 1, $0 \prec \mu_{\tilde{A}}(x) \prec 1$.

Core, support and boundary are the standard areas defined functions of membership. There are two additional important terms in this context:

(4) Crossover point

A membership function crossover point is the component in a universe whose membership value is equal to half (0.5), $\mu_{\tilde{A}}(x) = 0.5$.

(5) Height
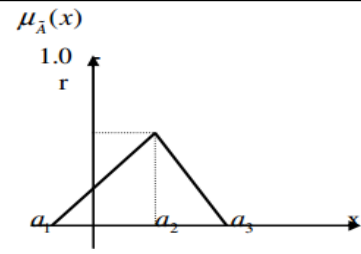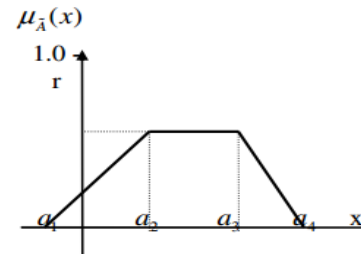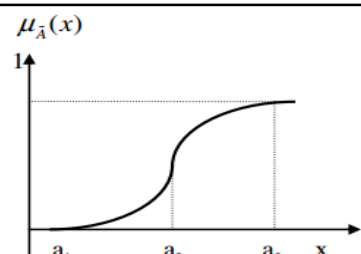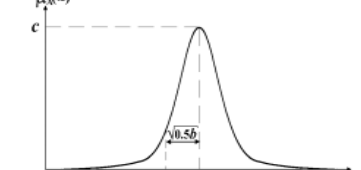
The height of the fuzzy set $\tilde{A}$ is the maximum value that a membership function can reach, max ($\mu_{\tilde{A}}(x)$). The functions of membership can be asymmetrical or symmetrical, that takes value between 0 and 1.

Typical Membership Functions

Generally, it is effective to characterize the most important typical membership functions by a functions-parameterized family[1]. The following table 4.2 describes the standard membership functions.

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[1] Janusz Kacprzyk, *Studies in Fuzziness and Soft Computing,* (Poland: Springer, 2013), 04.

Table (4.2): Typical membership functions

Type of Membership function	Graphical Representation	Analytical Representation
Triangular MF	$\mu_{\tilde{A}}(x)$	$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} r, & \text{if } a_1 \leq x \leq a_2, \\ \dfrac{a_3 - x}{a_3 - a_2} r, & \text{if } a_2 \leq x \leq a_3, \\ 0, & \text{otherwise} \end{cases}$
Trapezoidal MF	$\mu_{\tilde{A}}(x)$	$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} r, & \text{if } a_1 \leq x \leq a_2, \\ r, & \text{if } a_2 \leq x \leq a_3, \\ \dfrac{a_4 - x}{a_4 - a_3} r, & \text{if } a_3 \leq x \leq a_4, \\ 0, & \text{otherwise} \end{cases}$
S - shaped MF	$\mu_{\tilde{A}}(x)$	$\mu_{\tilde{A}}(x) = \begin{cases} 0, & \text{if } x \leq a_1, \\ 2\left(\dfrac{x - a_1}{a_3 - a_1}\right)^2, & \text{if } a_1 < x < a_2, \\ 1 - 2\left(\dfrac{x - a_1}{a_3 - a_1}\right)^2, & \text{if } a_2 \leq x < a_3, \\ 1, & \text{if } a_3 \leq x \end{cases}$
Bell - shaped MF	$\mu_{\tilde{A}}(x)$	$\mu_{\tilde{A}}(x) = c \cdot \exp\left(-\dfrac{(x - a)^2}{b}\right)$

Source: Janusz Kacprzyk, *Studies in Fuzziness and Soft Computing,* 05.

The above table summarizes the analytical and graphical representations of commonly utilized membership functions (MF). There are various methods for membership functions estimation. They can be categorized as follows[1]:

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[1] Ibid., 06.

1. Membership functions based on heuristics.

2. Membership functions based on reliability concepts with respect to the particular problem.

3. Membership functions based on more theoretical demand.

4. Membership functions as a model for human concepts.

5. Neural networks based construction of membership functions.

The estimation methods of membership functions based on more theoretical demand use axioms, probability density functions and so on.

To illustrate the concepts, an example is presented here. Consider three fuzzy sets that represent the concepts of a young, middle-aged and old person. A trapezoidal membership function A1, A2 and A3 is shown in the next figure[1]. These functions are defined on the interval [0, 80] as follows:

$$A_1(x) = \begin{cases} 1 & when\ x \leq 20 \\ (35 - x)/15 & when\ 20 < x < 35 \\ 0 & when\ x \geq 35 \end{cases} \tag{4.44}$$

$$A_2(x) = \begin{cases} 0 & when\ either\ x \leq 20\ or\ \geq 60 \\ \frac{(x-20)}{15} & when\ 20 < x < 35 \\ \frac{(60-x)}{15} & when\ 45 < x < 60 \\ 1 & when\ 35 \leq x \leq 45 \end{cases} \tag{4.45}$$

$$A_3(x) = \begin{cases} 0 & when\ x \leq 45 \\ (x - 45)/15 & when\ 45 < x < 60 \\ 1 & when\ x \geq 60 \end{cases} \tag{4.46}$$

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[1] Georgr J. Klir, Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications,* 19.

A possible discrete approximation, D_2, of function A_2, is shown in figure 4.9 as well. Its explicit definition is given in Table 4.3. Such approximations are important because they are typical in computer representations of fuzzy sets.
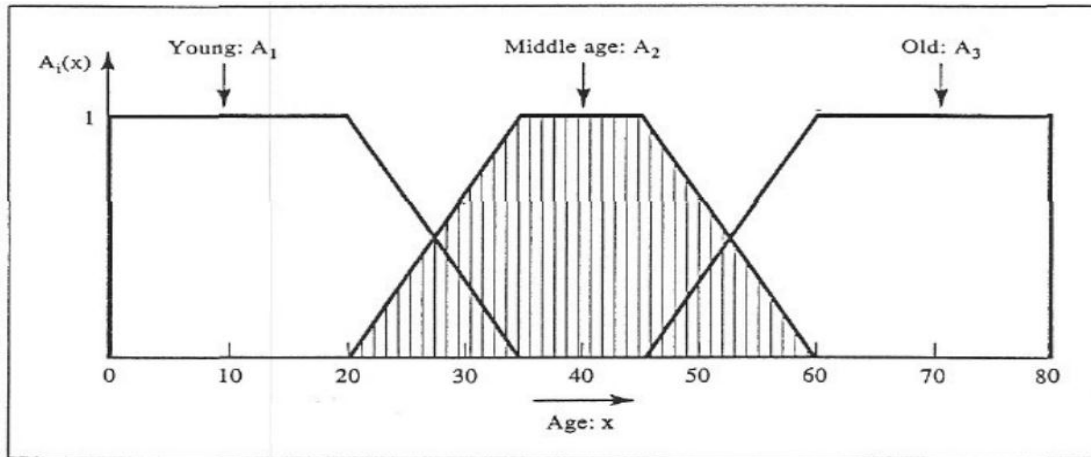
Figure (4.9): Membership Function Representing the Concept of a young, middle-aged and old person.

Source: George J. Klir, Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications,* 20.

Table (4.3): Discrete Approximation of Membership Function A2 by Function D2 of the Form D_2 :{ 0, 2, 4, …, 80} → [0, 1]

X	$D_2(x)$
$x \notin \{22, 24, …, 58\}$	0.00
$x \in \{22, 58\}$	0.13
$x \in \{24, 56\}$	0.27
$x \in \{26, 54\}$	0.40
$x \in \{28, 52\}$	*0.53*
$x \in \{30, 50\}$	*0.67*
$x \in \{32, 48\}$	*0.80*
$x \in \{43, 46\}$	*0.93*
$x \in \{36, 38, …, 44\}$	*1.00*

Source: Georgr J. Klir, Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications,* 20.

4.1.2.2.   Basic Operations on Fuzzy sets

Considering three fuzzy sets $\tilde{A}, \tilde{B}$, and $\tilde{C}$ on the universe X. For a given element x of the universe, the following function of theoretic operations for the set of theoretic operations unions, intersection and complement are defined for $\tilde{A}, \tilde{B}$, and $\tilde{C}$ on X as follow[1]:

✓   **Union**

The membership value of member x in the union takes the greater value of membership between A and B

$$\mu_{\tilde{A}\cup\tilde{B}}(x) = Max[\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)], \forall x \in X \tag{4.47}$$
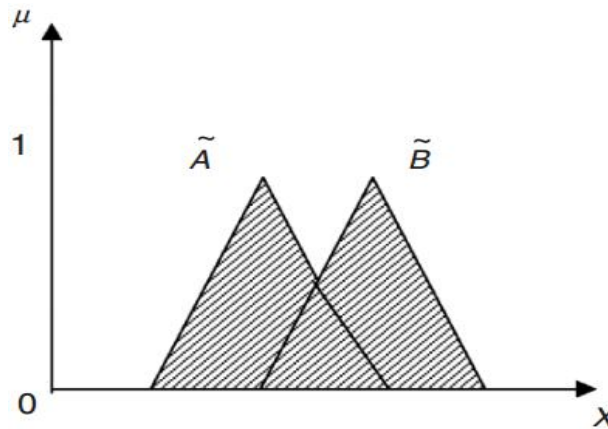
Figure (4.10): Union of Fuzzy Sets

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 21.

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[1] Kwang H. Lee, *First Course on Fuzzy Theory and Applications,* (Berlin: Spring, 2005), 21.

✓   **Intersection**

Intersection of fuzzy sets $\tilde{A}$ and $\tilde{B}$ takes smaller value of membership function between $\tilde{A}$ and $\tilde{B}$.

$$\mu_{\tilde{A} \cap \tilde{B}}(x) = Min[\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)], \forall x \in X \tag{4.48}$$
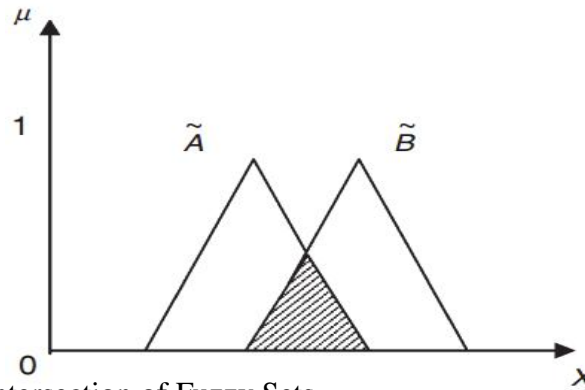
Figure (4.11): Intersection of Fuzzy Sets

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 21.

✓   **Complement**

We can find complement set of fuzzy set $\tilde{A}$ likewise in crisp set. We denote the complement set of $\tilde{A}$ as $\overline{\tilde{A}}$. Membership degree can be calculated as following[1].

$$\mu_{\overline{\tilde{A}}}(x) = 1 - \mu_{A}(x), \forall x \in X \tag{4.49}$$

---

[1] Ibid.
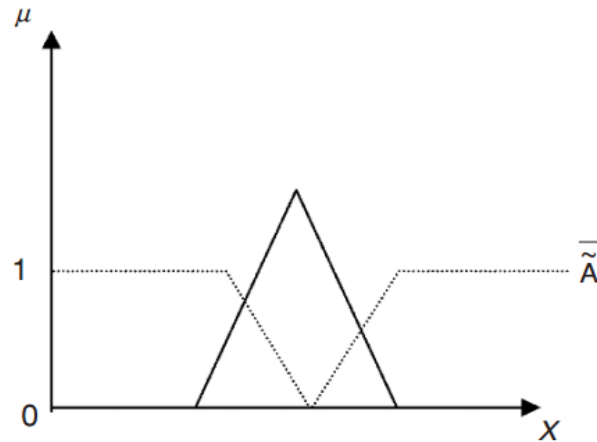
Figure (4.12): Complement of Fuzzy Sets

Source: N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 22.

4.1.2.3.   Properties of Fuzzy Sets

The properties of fuzzy sets have a big similarity to the classical sets properties. The main characteristics of fuzzy sets are addressed as follow[1]:

Commutativity

$$\tilde{A} \cup \tilde{B} = \tilde{B} \cup \tilde{A} \tag{4.50}$$

$$\tilde{A} \cap \tilde{B} = \tilde{B} \cap \tilde{A} \tag{4.51}$$

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[1] N. Sivanandam, S. Sumathi and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*, 22.

Associativity

$$\tilde{A} \cup (\tilde{B} \cup \tilde{C}) = (\tilde{A} \cup \tilde{B}) \cup \tilde{C} \qquad (4.52)$$

$$\tilde{A} \cap (\tilde{B} \cap \tilde{C}) = (\tilde{A} \cap \tilde{B}) \cap \tilde{C} \qquad (4.53)$$

Distributivity

$$\tilde{A} \cup (\tilde{B} \cap \tilde{C}) = (\tilde{A} \cup \tilde{B}) \cap (\tilde{A} \cup \tilde{C}) \qquad (4.54)$$

$$\tilde{A} \cap (\tilde{B} \cup \tilde{C}) = (\tilde{A} \cap \tilde{B}) \cup (\tilde{A} \cap \tilde{C}) \qquad (4.55)$$

Idempotency

$$\tilde{A} \cup \tilde{A} = \tilde{A}$$
$$\tilde{A} \cap \tilde{A} = \tilde{A} \qquad (4.56)$$

Identity

$$\tilde{A} \cup \phi = \tilde{A} \quad \text{and} \quad \tilde{A} \cap X = A \qquad (4.57)$$

$$\tilde{A} \cap \phi = \phi \quad \text{and} \quad \tilde{A} \cup X = \tilde{X} \qquad (4.58)$$

Transitivity

If $\qquad\qquad \tilde{A} \subset \tilde{B} \subset \tilde{C}$ then $\tilde{A} \subset \tilde{C} \qquad (4.59)$

Involution

$$\overline{\overline{\tilde{A}}} = \tilde{A} \qquad (4.60)$$

The above relations show the main properties of fuzzy sets.

4.2.   Traditional Regression Analysis

In the following section, we will discuss the regression and its nature, since regression is a common process in the field of econometrics and is one of the highly important methods useful to analyze economic data.

4.2.1.   The Origin and Definition of the Term Regression

Etymologically speaking, Francis Galton introduced the term regression for the first time. The argument of regression is based on the fact that, even though it is frequently common for tall parents to have tall children and uncommon for short parents to have tall children, the average height of children would change. Galton published a famous paper entitled *Family Likeness in Stature* where he explained that argument, stating that the average height of children would "regress" or move away from the height of their parents, towards the average height in the population as a whole[1]. His friend Karl Pearson[2] confirmed his law of universal regression when he recorded the heights of more than a thousand family members in his research *On the Laws of Inheritance*. He found that the height of the new generation was similar to the average height of all men in the society, that fact that Galton termed as the "regression to mediocrity".

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[1] Francis Galton, "Family Likeness in Stature," *Proceedings of Royal Society, London, Online* vol. 40 (1886): 42–72, accessed Aug 2, 2016, http://galton.org/essays/1880-1889/galton-1886-family-likeness-stature.pdf

[2] K. Pearson and A. Lee, "On the Laws of Inheritance,'' *Biometrika,* vol. 2, (1903): 357-462, accessed   Sep   10,   2016, http://www.medicine.mcgill.ca/epidemiology/hanley/c607/ch10/pearson_1902_sect_1_4.pdf

4.2.1.1.   The Definition of Regression

Regression analysis investigates of the relationship between one variable (the dependent variable) and one or more other variables (the explanatory variables) and its dependency on it/ them. This is accomplished at the same time by estimating the (population) average value of the dependent variable in terms of the fixed values the explanatory variables in the repeated sampling.

Dependent variable ⇔ Controlled Variable ⇔ Endogenous ⇔ Regressand ⇔ Response ⇔ Predictand ⇔ Outcome ⇔ Explained Variable.

Independent variable ⇔ Explanatory Variable ⇔ Regressor ⇔ predictor ⇔ Exogenous ⇔ Control Variable ⇔ Stimulus ⇔ Covariate.

4.2.1.2.   The Uses of Regression Analysis

Normally regression analyses are used for at least one of the three cases below:

(1) Forecasting the target variable.

(2) Demonstrating the relationship between the dependent and independent variables.

(3) Testing the hypotheses.

4.2.2.   Types of Regression

There are many types of regression, but in the following session we will focus on the two main types of regression: linear and nonlinear regression models because they are the most frequent used models.

4.2.2.1.   Linear and Nonlinear Regression Models

There are two main subcategories of regression[1]:

a. **The linear regression**: It in turn includes two divisions

✓ The simple linear regression: It includes only one explanatory variable, using the following regression equation:

$$y = \beta_0 + \beta_1 X_i + e_i \tag{4.61}$$

✓ The multiple linear regression: It contains more explanatory variables and generally takes the following form:

$$y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_m X_{im} + e_i \tag{4.62}$$

b. **Nonlinear Regression:** it is also divided into two parts:

✓ Simple Nonlinear regression: It includes only one explanatory variable as in the following equation:

$$y_i = \beta_0 e^{\beta_1 X} \mu \tag{4.63}$$

✓ Multiple nonlinear regression: It includes more than one explanatory variable, as in the following example used by the Cobb-Doglas Production Function:

$$y = AL^{\alpha} K^{\beta} \tag{4.64}$$

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[1] Yara Mohammed Al sarem, "The Contribution of the Variance Analysis in the Design of Statistical Experiments and its Relationship with Regression Analysis", Master Degree dissertation., Faculty of Sciences, Department of mathematical Statistics, Aleppo University, 2010, 83.

By using the logarithm transformation, the nonlinear equations can be transferred into linear regressions.

4.2.2.2.   The Traditional Simple and Multiple Linear Regression

The simple linear regression analysis model is regarded as one of the most frequent models in econometrics. The linear regression is considered simple when it examines only one explanatory variable and represents a linear relationship between the dependent and independent variable.

A scatter gram or the scatter plot of the data **x** and **y** is a useful way to start the regression analyses. It shows whether a relationship between the two variables x_i and y_i exists or not.
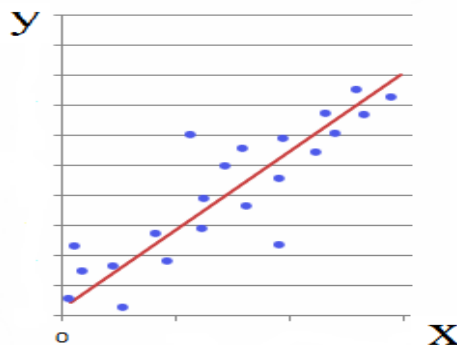
Figure (4.13): The Scatter Plot and the Fitting Regression line

Source: Dominick Salvatore, "*Managerial Economics*"6th edition, (Beijing: Oxford University Press, 2007), 126.

The simple linear regression model takes the following form:

$$Y_i = a + bX_i + U_i \tag{4.65}$$

Where:

Yi represents the values of the dependent variable.

Xi denotes the values of the explanatory variables.

B indicates the slope of the regression line.

U$_i$ shows the values of the error.

The multiple linear regression is the normal extension of the simple regression. It enlarge the number of the explanatory variables, and it is close to the real situations in the economy. The following example clarifies this. The quantity demand from a product can be affected by other factors more than the price alone, like the existence of a substitute, the tastes of the customers, their incomes, the supplied quantity … etc. The multiple linear regression can take the following form:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_K x_k + U_i \qquad (4.66)$$

K represents the number of the added explanatory variable.

Many methods can be used to estimate the coefficients for the above equations, but the ordinary least square method is the best example used because of multiple reasons, as we will see below.

4.2.3.   Ordinary Least Square Estimation Method

Ordinary Least Square Estimation Method is regarded as one of the most important methods in estimating the statistical relationships in the regression analyses. The following section tackles the method vividly.

4.2.3.1.   Reasons for Favoring the OLS Estimation Method

Alternative methods of OLS are necessary in some cases, but in most situations, OLS remains the most popular technique for estimating regression mainly for three reasons[1]:

- ✓ Using the OLS is easier, efficient and more practical than other alternatives. Other useful methods such as the Generalized Method of the Moment (GMM) and the Maximum likelihood (ML) require more mathematical sophistication and more computing processes, although these days the computing power is available through computer software.

- ✓ OLS is sensible in that, when using squared residuals one can avoid the deleting of the positive and negative residuals to each other, and can find a regression line that is very close to the observed data factors.

- ✓ Most of the other estimation methods contain an application or process of the Ordinary Least Square Method.

OLS results have needed and targeted characteristics. One of the attributes required from any estimator, is for it to be a good predictor. When OLS is used, the next helpful statistical qualities are related to the results:

❖ The regression line always passes through the sample means of *Y* and *X*, in other words:

$$\overline{Y} = \hat{\beta}_0 + \hat{\beta}_1 \overline{X}. \tag{4.67}$$

❖ The mean of the estimated value of *Y* is equal to the mean value of the actual Y or

$$\overline{\hat{Y}} = \overline{Y}. \tag{4.68}$$

❖ The mean of the residuals is zero, or

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[1] Roberto Pedace, *Econometric for Dummies*. (New Jersey: John Wiley & Sons, Inc., 2013), 76.

$$\bar{\hat{\varepsilon}} = 0. \tag{4.69}$$

❖ The residuals are not associated with the predicted *Y*, or

$$\sum_{i=1}^{n}(Y_i - \bar{Y})\hat{\varepsilon}_i = 0. \tag{4.70}$$

❖ The residuals are not associated with the observed values of the independent variables,

or

$$\sum_{i=1}^{n}\hat{\varepsilon}_i X_i = 0. \tag{4.71}$$

The proprieties of the OLS method are used to prove various things in the field of in econometrics. They demonstrate that, on a regular level, the estimation will be perfect. The regression line that passes through the sample means, the mean of the estimations equaling the mean of the data values in addition to the fact that the average residual will be zero altogether stand in favor of this estimation method.

4.2.3.2.   Estimating Parameters Using OLS

The analysis of the regression is a statistical method used to gain the most appropriate line suitable for the data points following objective statistical standards. The aim is that the researchers looking at the similar data get the same result (i.e., obtain the same line). Minimizing the sum of the squared vertical deviation $\left(\sum e_i^2\right)$ of each point from the regression line is precisely what establishes the regression line. This method is termed the "Ordinary Least Square Method". The purpose of regression analyses is to attain estimations for both (a) the vertical intercept and (b) the slope of the regression line[1]:

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[1] Dominick Salvatore, *Managerial Economics*. 6th edition, (Beijing: Oxford University Press, 2007), 127.

$$\hat{Y}_t = \hat{a} + \hat{b}X_t \tag{4.72}$$

$\hat{Y}_t$ denotes the estimation of Y in a given year t, and they have been taken from the regression line. $\hat{a}$ and $\hat{b}$, on the other hand, are estimations for the parameters a and b consecutively. The deviation of errors (e_t) of every detected value (Y_t) from its related value that is estimated from the regression line $(\hat{Y}_t)$ is then[1]:

$$e_t = Y_t - \hat{Y}_t = Y_t - \hat{a} - bX_t \tag{4.73}$$

The sum of these squared errors or deviances can, therefore, be calculated as:

$$\sum_{t=1}^{n} e_t^{2} = \sum_{t=1}^{n} (Y_t - \hat{Y}_t)^{2} = \sum_{t=1}^{n} (Y_t - \hat{a} - \hat{b}X_t)^{2} \tag{4.74}$$

Where $\sum_{t=1}^{n}$ equals the amount of all observations for t =1….n.

It is intentional to square the errors then add them to avoid the cancellation of the errors identical in size and opposite signs. Squaring the errors is also sufficient to rectify major errors more than trivial minor ones.

The values of a and b are estimated through reducing the amount of the squared deviations. The value of $\hat{b}$ is given by:

$$\hat{b} = \frac{\sum_{t=1}^{n} (X_t - \bar{X})(Y_t - \bar{Y})}{\sum_{t=1}^{n} (X_t - \bar{X})^2} \tag{4.75}$$

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[1] Ibid., 127-128.

Where $\bar{Y}$ and $\bar{X}$ are the mean or average values of Y_t and X_t consecutively. The value of $\hat{a}$ is then taken from:

$$\hat{a} = \bar{Y} - \hat{b}\bar{X} \tag{4.76}$$

Through calculating the partial derivative of equation (4.73), we can discern values of $\hat{a}$ and $\hat{b}$. This is accomplished with respect to $\hat{a}$ and $\hat{b}$, laying the resulting two normal equations equal to zero and solving them at the same time to achieve equation[1] (4.74)

4.2.3.3.   Ordinary Least Square Method Assumptions

The ordinary least square method assumptions include the criteria that set the requirements that one must apply. The following is their complete set[2]:

- ✓ The OLS method is linear in its standards and has an extra error term.

- ✓ An arbitrary sample of the population that includes changeability is the basic fundament that helps originate the values of the explanatory variable.

- ✓ There is no perfect collinearity, i.e.: no explanatory variable has a perfect linear function for any other explanatory variable(s).

- ✓ The method is identified in the approved manner and there is a zero conditional mean for the error term: $E(\mu_i|X_i) = 0$

- ✓ There exists no heteroscedasticity: i.e.: there occurs a constant variance at the level of the error term.

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[1] Ibid., 129.
[2] Roberto Pedace, *Econometric for Dummies*, 94.

✓ There is no correlation/ no serial correlation i.e.: the values of the error term are not correlated with each other.

4.2.3.4. Properties of Ordinary Least Square Estimators

Under the normality assumption for U_i, the estimated parameters using OLS method have the following properties[1]:

1. The Ordinary Least Square estimators are linear.

2. The estimators are unbiased. $E(\hat{\beta_1}) = \beta_1$

3. The estimators have minimum variance. $Var(\hat{\beta_1}) = \dfrac{\sum X_i^2}{n \sum x_i^2} \sigma^2$

4. The OLS estimators have consistency; that is, as the sample size increases indefinitely, the estimators converge to their true population values.

❖ Gauss-Markov Theorem states that the OLS estimator is the best linear unbiased estimator (BLUE).

4.3. Fuzzy Regression

Fuzzy regression and traditional regression analyses are similar in the fact that the relationship of their dependent and independent variables is usually assumed to have a specific mathematical form with at least one independent variable. However, the difference between them lies in the disparity of the data each of them treats. Whilst statistical regression analysis is a part of statistics that studies the relationship between the dependent variable and

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[1] Damodar N.Gujarati, "*Basic Econometrics*" ,4th edition, (New York: McGraw-Hill Companies, Inc., 2003), 110.

the independent variables, fuzzy regression studies both classical (crisp) data as well as fuzzy data along with fuzzy coefficients.

4.3.1.   Origin and Definition of Fuzzy Regression

The fuzzy regression can be defined through separating this term into two main parts. Firstly, the word regression which represents statistical techniques between the dependent variable and the explanatory variables, wherein the dependent variable is considered as a function in the explanatory variables in order to illustrate the strength and the direction of the relationship through estimating the parameters of the model. Secondly, the word fuzzy indicates the fuzzy logic that we have seen in the beginning of this chapter, and which was introduced by the expert Lotfi Zadeh (1973) as a better alternative method in treating the data and estimating and solving problems.

Fuzzy regression was developed by researchers due to two main reasons. Firstly, it is developed because it is normally unrealistic to think that a crisp function of any form represents the relationship between the given variables. Fuzzy relations are scientifically more realistic, even though they are less exact. Secondly, the nature of data in some applications is fundamentally fuzzy. It is because of these two reasons that the two types of fuzzy regression analyses were established. Fuzzy regression has two subcategories, fuzzy linear regression and the Tanaka fuzzy linear programming method.

4.3.2.   Fuzzy Regression Methods

Based on previous studies, the fuzzy regression can be categorized into two basic methods. The first method depends on Linear Programming Approach (LP) which was introduced by Tanaka (1982). The second one is Fuzzy Least Square Approach (FLS)[1].

4.3.2.1.   Linear Programming Approach of Tanaka

Linear Programming Approach is also known as Possibilistic Regression Analysis[2]. This method was introduced by Tanaka (1982), where he estimated fuzzy regression model coefficients through solving a linear programming problem by using crisp inputs as explanatory variables in order to get a fuzzy output (STFN) (dependent variable). This approach generally aims to minimize the fuzziness of the model by minimizing the total spread of the fuzzy coefficients. It is applicable to both crisp data and fuzzy data in regression models, and it is regarded as an extension of classical regression analyses where the fuzzy numbers denote some variables of the estimated model. Tanaka explained the fuzzy regression model as follows:

The fuzzy regression model takes the following form:

$$\tilde{Y}_j = \tilde{A}_0 + \tilde{A}_1 X_{1j} + ... + \tilde{A}_m X_{mj} \qquad (4.77)$$

Where:

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[1] Miin-Shen Yang, Hsien –Hsien Liu, "Fuzzy Least Square Algorithms for Interactive fuzzy linear Regression Models", *Fuzzy Sets and Systems*, Vol. 135, (2003), 306.
[2] Hideo Tanaka, Haekwan Lee , "Interval Regression Analysis by Quadratic Programming Approach", *IEEE Transactions on Fuzzy System*, Vol.6, No.4.(1988), 473.

$\tilde{Y}_j$ indicates the value of the dependent variable with regard to the views j,

$j = 1, 2, ...n, n \succ m$.

X_{ij} represents the value of the independent variable with regard to the view j, $i = 0, 1, ..., m$.

m denotes the number of independent variables which are not a fuzzy number.

$\tilde{A}_i$ represents the model coefficients which are fuzzy numbers.

It is assumed that the dependent variable Y_j is a symmetric triangular fuzzy number (STFN), which can be represented as follows:

$$\tilde{Y}_j = \left(Y_{jC}, Y_{jR} \right) \tag{4.78}$$

Where,

Y_{jC} represents the center of the dependent fuzzy number.

Y_{jR} Indicates the spread of the dependent fuzzy number, and therefore, the cut $-\alpha$ of the fuzzy number $\tilde{Y}_j$ is symbolized by $\tilde{Y}_{j\alpha}$, and is represented as follows[1]:

$$Y_{j\alpha} = \left\langle \grave{}Y_{jC}, \grave{}Y_{jR} \right\rangle = \left[Y_{jC} - Y_{jR}(1-\alpha), Y_{jC} + Y_{jR}(1-\alpha) \right] \tag{4.79}$$

Where:

$\grave{}Y_{jC}$ represents the center of the cut $-\alpha$ of the dependent variable.

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[1] Jorge de Andrés Sánchez, Antonio Terceño Gómez., "Estimating a term Structure of Interest Rates For Fuzzy Financial Pricing by Using Fuzzy Regression Methods", *Fuzzy sets and systems*, Vol.139,(2003), 672.

$\grave{Y}_{jR}$ represents the spread of the cut $-\alpha$ of the dependent variable.

The main objective is to get the fuzzy numbers $\hat{\tilde{A}}_i$, which estimate the coefficients of the model $\tilde{A}_i$ by using the available data. The coefficients $\tilde{A}_i$ should be a symmetric triangular fuzzy number (STFN). These coefficients are written as follows:

$$\tilde{A}_i = (a_{iC}, a_{iR}), \qquad i = 0,1,2, \ldots \ldots m \tag{4.80}$$

Thus, the fuzzy model coefficient can be written as follows:

$$\hat{\tilde{A}}_i = (\hat{a}_{iC}, \hat{a}_{iR}) \tag{4.81}$$

After getting the coefficients $\hat{\tilde{A}}_i$, the estimated model is written like:

$$\hat{\tilde{Y}}_j = \hat{\tilde{A}}_0 + \hat{\tilde{A}}_1 X_{1j} + \ldots \ldots + \hat{\tilde{A}}_m X_{mj} \tag{4.82}$$

Likewise, $\hat{\tilde{Y}}_j$ can be written as follows:

$$\begin{aligned} \hat{\tilde{Y}}_j &= \left(\hat{Y}_{jC}, \hat{Y}_{jR}\right) = \left(\hat{a}_{0C}, \hat{a}_{0R}\right) + \left(\hat{a}_{1C}, \hat{a}_{1R}\right) X_{1j} + \cdots \cdots + \left(\hat{a}_{mC}, \hat{a}_{mR}\right) X_{mj} . \\ &= \left(\hat{a}_{0C} + \hat{a}_{1C} X_{1j} + \cdots + \hat{a}_{mC} X_{mj} , \hat{a}_{0R} + \hat{a}_{1R} X_{1j} + \cdots + \hat{a}_{mR} X_{mj}\right) \\ &= \left(\sum_{i=0}^{m} \hat{a}_{iC} X_{ij} , \sum_{i=0}^{m} \hat{a}_{iR} \left|X_{ij}\right|\right) \end{aligned} \tag{4.83}$$

The cut $-\alpha$ from the fuzzy number $\hat{\tilde{Y}}_j$ can take the following shape:

$$= \left[\sum_{i=0}^{m} \hat{a}_{iC} X_{ij} - (1-\alpha)\sum_{i=0}^{m} \hat{a}_{iR} \left|X_{ij}\right|, \sum_{i=0}^{m} \hat{a}_{iC} X_{ij} + (1-a)\sum_{i=0}^{m} \hat{a}_{iR} \left|X_{ij}\right|\right] \tag{4.84}$$

In order to get the parameters $\hat{a}_{iC}$ and $\hat{a}_{iR}$ the spread of $\hat{\tilde{Y}}_j$ must be minimized and in the same time maximize $\mu\left(Y_j \subseteq \hat{\tilde{Y}}_j\right)$, where,

Y_j Represents the value of the dependent variable relative to the view j

$\hat{\tilde{Y}}_j$ Indicates the fuzzy estimation of Y_j.

The linear programming problem specifically must be solved

$$\text{Minimize} \, Z = \sum_{i=1}^{n} \hat{Y}_{jR} = \sum_{j=1}^{n}\sum_{i=0}^{m} \hat{a}_{iR}\left|X_{ij}\right| \quad , \quad \text{Maximize} \; \alpha$$

Under the condition that:

$$\mu\left(Y_j \subseteq \hat{\tilde{Y}}_j\right) \geq \alpha \; , \qquad j = 1,2,........m \; , \qquad i = 0,1,2,........m, \qquad \hat{a}_{iR} \geq 0 \,, \qquad a \in [0,1]$$

(4.85)

Hence, it is referred to the level of the cut $-a$ in the fuzzy regression model as a measurement of the membership or the compatibility between the estimated fuzzy regression model and the data which means that Y_j must belong to $\hat{\tilde{Y}}_j$ with a membership level greater or equal to α.

4.3.2.2.   Fuzzy Least Square Regression Methods

There are various ways to implement the Fuzzy Least Square Regression method (FLSR); however, the basic two approaches are Fuzzy Least Square Regression using

distance measures and Fuzzy Least Square Regression using compatibility measures. An explanation of these approaches follows below[1].

> ➢ **FLSR Using Distance Measures Method**

Diamond (1988) was the first to introduce the Fuzzy Linear Square Regression using distance measures through defining a measurement to calculate the distance between two triangular fuzzy numbers based on their centers and their left and right spread. This measurement takes the following shape:

$$d\left(\langle m_1, l_1, r_1 \rangle, \langle m_2, l_2, r_2 \rangle\right)^2 = \left(m_1 - m_2\right)^2 + \left(\left(m_1 - l_1\right) - \left(m_2 - l_2\right)\right)^2 + \left(\left(m_1 + r_1\right) - \left(m_2 + r_2\right)\right)^2 \quad (4.86)$$

Where

d refers to the distance

m_1 indicates the center of the first fuzzy number, l_1 is the left spread , while, r_1 is the right spread.

m_2 denotes the center of the second fuzzy number, l_2 is the left spread , while, r_2 is the right spread. According to this method, the objective function is to minimize the sum squares of the distances between Y_j and $\hat{\tilde{Y}}_j$.

$$\min \sum d\left(\hat{\tilde{Y}}_i - \tilde{Y}_i \right) \quad (4.87)$$

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[1] Arnold F., Shapiro, "Fuzzy Regression models", *Society of Actuaries (SOA)*, (2007), 12.

➢ **FLSR Using Compatibility Measures Method**

Celmiṇs (1987) was the first to implement FLSR using compatibility measures. He introduced a measure of compatibility between two fuzzy numbers $\tilde{A}$ and $\tilde{B}$. This measure is symbolized by $\gamma(\tilde{A},\tilde{B})$, it depends on their membership function $\mu_{\tilde{A}}(X)$, $\mu_{\tilde{B}}(X)$ as follows.

$$\gamma\left(\tilde{A},\tilde{B}\right)= A\max\min\left\{\ \mu_{\tilde{A}}(X),\mu_{\tilde{B}}(X)\ \right\} \tag{4.88}$$

The compatibility measure between $\tilde{A}$ and $\tilde{B}$ ranges from 0 to1, if this measure was 0, that means that there is no interference between the spread of $\tilde{A}$ and $\tilde{B}$, or there is no common part between the membership functions of $\tilde{A}$ and $\tilde{B}$. The following figure illustrates that[1]:
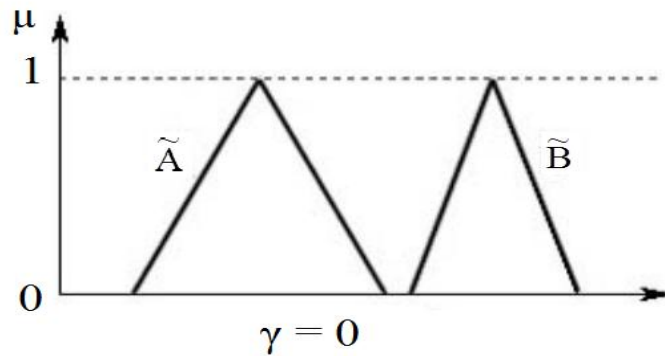
Figure (4.14): Celmiṇs Compatibility measure between $\tilde{A}$ and $\tilde{B}$ equal to 0

Source: Arnold F., Shapiro, "Fuzzy Regression models", *Society of Actuaries (SOA)*, (2007), 14.

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[1] Ibid.,12.

If the membership functions of $\tilde{A}$ and $\tilde{B}$ are identical or their centers are identical, that means the compatibility in this case is equal to 01. The following figure illustrates that:
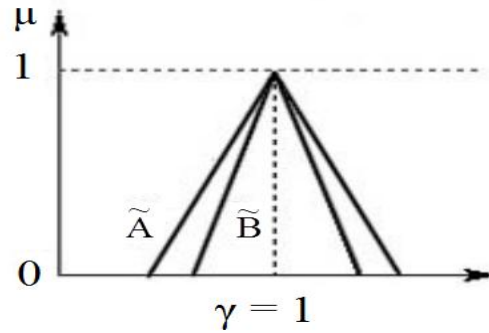
Figure (4.15): Celmiņs Compatibility measure between $\tilde{A}$ and $\tilde{B}$ equal to 1

Source: Arnold F., Shapiro, "Fuzzy Regression models", *Society of Actuaries (SOA)*, (2007), 14.

Therefore, by using the compatibility measure method in estimating a fuzzy least square regression model, the compatibility between the data of the dependent variable and the estimated values of it must be maximized.

4.3.2.3. The Advantages of Fuzzy Regression

Fuzzy regression might perform better than statistical regression in the following cases[1]:

- ✓ Insufficient data to support statistical regression analysis.

- ✓ The statistical distribution cannot be justified.

- ✓ If the aptness of the regression model is poor.

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[1] S. Arulchinnappan, "A study on Fuzzy Linear Regression", PhD dissertation, Faculty of Science and Humanities ANNA University, 2012, 6. Accessed March 11, 2016. Shodhganga: a reservoir of Indian theses (http://hdl.handle.net/10603/17758).

✓ When human judgments are involved.

✓ Inaccurate data.

4.3.3. Fuzzy Regression Versus Traditional Regression

In this part, the differences between the fuzzy regression and the traditional regression will be addressed.

4.3.3.1. Basic Assumptions

The form of the traditional model of regression that contains m number of explanatory variables X_1, X_2, …, X_m, which is known as the Multiple Regression Model is as follows:

$$Y_j = \beta_0 + \beta_1 X_{1j} + \beta_2 X_{2j} + \cdots\cdots + \beta_m X_{mj} + \varepsilon_j \qquad (4.89)$$

Where:

Y_j represents the value of the dependent variable according to the datum j.

n represents the sample size, $\quad j = 1, 2, 3, …, n, \quad n > m$

X_{ij} indicates the value of the independent variables i regarding to the datum j.

m represents the number of the independent variables, $i = 1, 2, 3, …, m$.

$\beta_i \ i = 0, 1, 2, 3, …, m$ denotes the traditional regression parameters. These parameters are unknown and we must estimate them.

$\varepsilon_j \quad$ represents the model error, which is also known as Random Error.

The values of $\hat{Y}$ are estimated through the following equation:

$$\hat{Y} = b_0 + b_1 X_{1j} + ... + b_m X_{mj} + e_j \qquad (4.90)$$

Where:

$b_0, b_1, ……, b_m$ represent the estimated parameters for $\beta_0, \beta_1, ……, \beta_m$

e_j denotes the Residuals, which represent the difference between the real value and the estimated value of the dependent variable.

$$e_j = Y_j - Y_j \qquad (4.91)$$

The estimated values of the parameters are obtained by using Ordinary Least Square method.

The traditional regression has rigid and determined assumptions[1] about the statistical characteristics of the model. Where it is assumed that the error ε_j is a random variable following the natural distribution with a mean equal to 0 and a fixed variance or Homogeneous variation for every j besides covariance between ε_j and ε_i is zero.

$$\varepsilon_j \sim N\left(0, \sigma^2\right) \qquad (4.92)$$

$$\text{Cov}\left(\varepsilon_i, \varepsilon_j\right) = 0 \qquad \forall i, j \qquad i \neq j \qquad (4.93)$$

That means, that there is no correlation between any two values of the error ε_j and ε_i. These assumptions are difficult to verify[2], unless a large number of data is available. In case these assumptions are not valid, that affects negatively the performance of the estimated model.

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[1] Thomas P. Ryan, *"Modern Regression Methods"*, (New Jersey: A John wiley & Sons, Inc Publication, 2009), 16.
[2] Chi – Bin Chen, "Non Parametric Fuzzy Regression and its Application", PhD Dissertation, College of Engineering, Kansas State University- Manhattan, 1998, 5.

The fuzzy regression uses a small size of the data sets. That is what makes it better than the traditional regression, especially for estimating the relationship between a fuzzy and limited datasets.

4.3.3.2. The Sources of the Random Error

The traditional regression assumes that the random error results from two main causes:

1- The factors excluded from the model.

2- Measurement errors.

While, the fuzzy regression assumes that the random error comes from

1- The inaccuracy of observation,

2- The vague relationship between the variables

4.3.3.3. The distribution of the Dependent Variable

Among the basic assumptions of the traditional regression is that the dependent variable follows the natural distribution. As for the fuzzy regression, the distribution of the dependent variably and basically depends on the shape of the membership function[1] of the estimated variables for the fuzzy model.

4.3.3.4. Usage

Both traditional regression and fuzzy regression require determining the form of the estimated model initially, which means choosing the dependent variable and the independent

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[1] Kwang Jae Kim, Herbert Moskowitz, Murat Koksalan. "Fuzzy Versus Statistical linear Regression", *European Journal of Operational Research*, Vol 92, 1996, 421.

variables and the form of the regression equation before using the data to estimate the parameters for the model. In addition to that, the fuzzy regression requires a predefinition for the value of a .

The estimated parameters in the traditional regression are considered as crisp numbers, while in the fuzzy regression, these parameters are fuzzy numbers consisting of a spread and a center, thus, the dependent variable is also a fuzzy number.

There is a difference between the confidence interval in the traditional regression and in the fuzzy regression. The following example describes that:

For example, in the case of creating a confidence interval at 95% for the mean of the dependent variable for the traditional regression and at the same time, creating fuzzy interval for the dependent variable for the fuzzy regression by using $a = 0.05$ the result would be different. The 0.95 for the confidence interval refers to the fact that 95% of the intervals would include the real value of the mean of the dependent variable in case a big number of separated samples was drawn and a confidence interval 95% was established for every single sample. The different result mentioned above lies in the fact that 95% of the intervals will contain the real value of the dependent value mean. Based on this explanation, it is clear that the confidence interval here is related to samples drawing.

However, on the other hand, and for the fuzzy interval, $a = 0.05$ reflects that every datum has a membership greater than or equal to aa0.95 for the estimated fuzzy interval[1].

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[1] Ibid., 422.

Chapter Conclusion

The fuzzy logic is considered as an extension of the finite logic. It allows us to treat both fuzzy and crisp data and find more realistic estimations, the fact which is contradictory to the traditional method which is restricted to true and false logic alone (yes or no, 1 or 0). The traditional regression, especially the OLS Estimation Method, is a very common estimation method in statistics for multiple reasons. However, its inability to treat fuzzy data and fuzzy parameters renders it less efficient than fuzzy regression. In this regard, fuzzy regression is more applicable because of its ability to treat both fuzzy data and crisp data, as well as fuzzy parameters. This means that fuzzy regression is more flexible and highly qualified and able to deal with more economic situations to ensure that the results we achieve are more realistic.

Chapter Five

Chapter Introduction

In this chapter, the environmental Kuznets Curve hypothesis for air pollution in Algeria will be examined by applying several estimation methods. Firstly, it will be estimated using the Ordinary Least Square estimation method, then, by employing the fuzzy linear regression model of Tanaka, and finally, by the Fuzzy least Square Regression method. These estimated models will be examined statistically and compared with the quality estimation. In the end, the findings will be discussed and interpreted economically in the light of the environmental Kuznets curve hypothesis.

5.1. Data Description and Model Specification

In this part, the data will be introduced statistically along with the environmental Kuznets curve hypothesis. Here we highlight the fact that all the estimation methods, which are the Ordinary Least Square Estimation Method, The Tanaka Method and The Fuzzy Least Square Estimation Method, are concerned with the same data sets and the same model, which is the environmental Kuznets Curve for air pollution in Algeria.

5.1.1. Data Description

This study estimates the relationship between the economic growth and environmental degradation in the environmental Kuznets curve frame by using annual data of CO_2 emissions in Algeria from 1970 to 2013 (measured in metric tons per capita) and real GDP per capita (measured in 2000 constant USD). These data were obtained from World Development Indicators (WDI) through World Bank database.

➕ CO_2 emissions: the World Bank defined second Carbon dioxide emissions as those elements coming from the burning of fossil fuels and the manufacturing of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring measured in metric tons per capita.
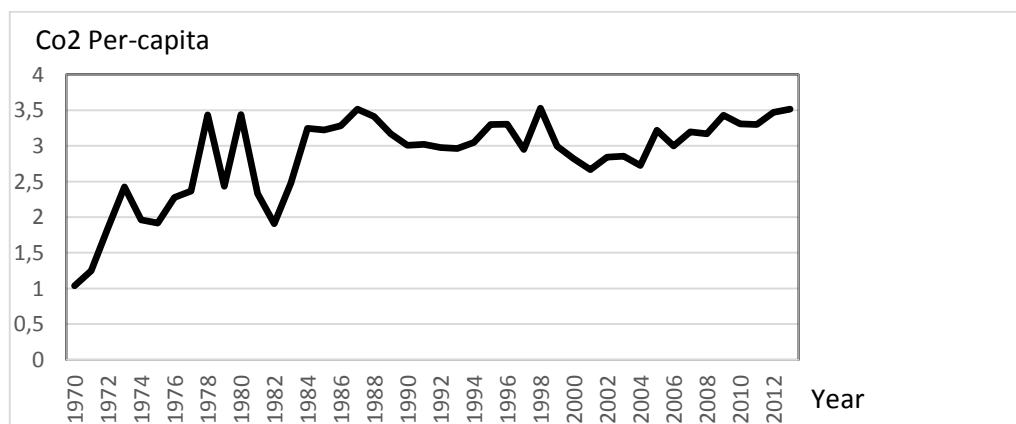
Figure (5.1): CO_2 Emissions Per capita in Algeria in the Period 1970-2013

Source: Compiled by the researcher based on the data that have been obtained from World

Bank database.

➕   Real GDP per capita: the World Bank defined the GDP as the total annual output of

a country's economy, here is in constant 2000 U.S. Dollars. GDP per capita is the total market

value of all final goods and services produced in a country in a given year, equal to total

consumer, investment, and government spending, divided by the midyear population.
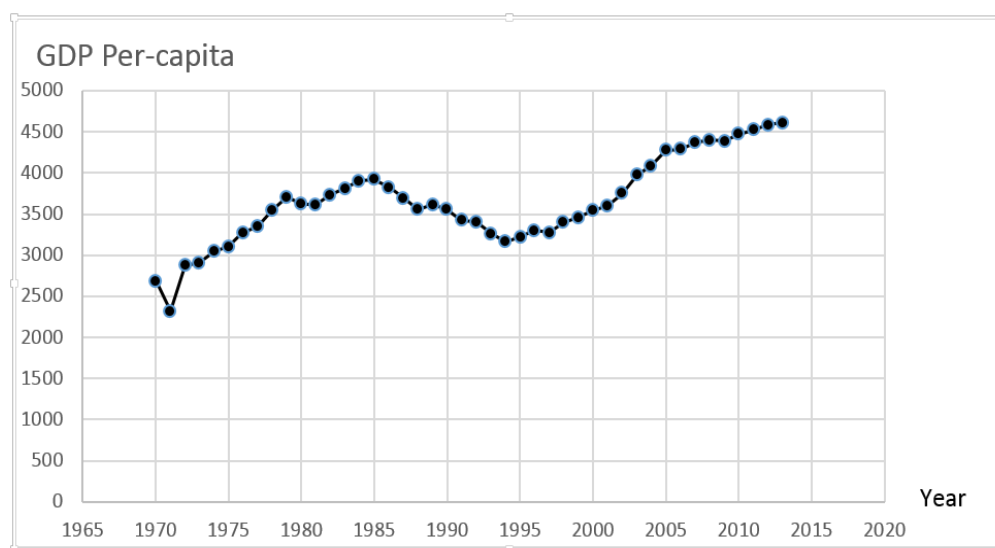
Figure (5.2): Algeria Real GDP per-capita

Source: Compiled by the Researcher based on World Bank data

        The following table shows the descriptive summary of statistics for the dependent

variable Ln CO_2 and the explanatory variables Ln GDP_{PC} and Ln GDP_{PC}^2 used in this study.

Table (5.1): Statistical Characteristics of data

Variable	Mean	Std. Dev.	Max	Min
CO_2	2.853755	0.606209	3.529700	1.036100
GDP_{PC}	3646.857	528.0890	4617.500	2322.100
GDP_{PC}^2	13572104	3866942	21321306	5392148

Source: Computed by the Author using Eviews08 software.

5.1.2.   Model Specification

Since the main objective of this study is testing the validity of environmental Kuznets curve for air pollution in Algeria, it would be useful to keep the model in its main form. This calls for the need to use the CO_2 as a proxy for air pollution and real GDP per capita to represent the economic growth in Algeria without including other additional explanatory variables to the model as excreted by Behnaz Saboori (2012)[1] and others. A quite standard parametric quadratic model in the EKC literature was considered.

The estimated model takes the following form

$$E_t = \beta_0 + \beta_1 Y_t + \beta_2 (Y_t)^2 + \varepsilon_t \tag{5.1}$$

Where, E_t represents CO_2 emissions per capita, Y_t , $(Y_t)^2$ is economic growth measured by real GDP per capita, the square value of real GDP per capita respectively and ε_t is standard error. As mentioned in the Second Chapter and according to the EKC hypotheses, the income coefficients values and signs for (β_1, β_2) indicate different functional forms. If $\beta_1 < 0$ and $\beta_2 > 0$ that will represent an U-shaped relationship while if $\beta_1 > 0$ and $\beta_2 < 0$ that indicates an inverted U-shaped relationship. $\beta_1 = \beta_2 = 0$ indicates a level relationship, $\beta_1 < 0$ and $\beta_1 = 0$ indicates a monotonically decreasing linear relationship, while $\beta_1 > 0$ and $\beta_2 = 0$ indicates a monotonically increasing linear relationship.

5.2.   The Estimation of EKC for air pollution in Algeria Using OLS Method

This section lays down the estimation of the environmental Kuznets Curve for air pollution in Algeria by using the OLS estimation method along with the statistical tests of the obtained results.

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[1] Behnaz Saboori n, et al, "Economic growth andCO2 emissions in Malaysia: A co-integration analysis of the Environmental Kuznets Curve". *Energy Policy* Vol. 51, (2012), 186, accessed Aug 21st , 2016, http://www.sciencedirect.com/science/article/pii/S0301421512007471

5.2.1.   The OLS Methodological Approach

The environmental Kuznets curve will be estimated at this stage. The CO_2 emissions per-capita is taken as a dependent variable while GDP and GDP^2 are used as explanatory variables in this model. The parameters of this model will be estimated by using the Ordinary Least Square Estimation method (OLS). This method relies on minimizing the sum of the squared of errors to the lowest possible level.

$$\text{Min} \sum_{t=1}^{n} e_t^2 = \text{Min} \sum_{t=1}^{n} (Y_t - \hat{Y}_t)^2 \tag{5.2}$$

Where $\sum_{t=1}^{n}$ equals the sum of all observations for t =1….n.

After estimating the EKC model parameters, those parameters will be statistically evaluated, through testing how fit the estimated model is.

5.2.2.   Empirical Results and Their Statistical Tests

In the next section, the application of the estimated air pollution model for Algeria will be executed, then, moving ahead with results discussion.

5.2.2.1.   The Empirical Results

The results of the estimation of environmental Kuznets curve for air pollution for Algeria using Ordinary Least Square method will be presented in this part. The EKC model will be estimated for the period (1970-2013) with 44 observations.

5.2.2.1.1. The Unit Root Test

Unless its probability distribution changes over time, a time series Y_t is stationary. Stationarity requires the future to be similar with the past, at least on probabilistic measures. Two tests are used to investigate whether our series subject to this study are stationary or not such as, the Augmented Dickey–Fuller (ADF) test (Dickey and Fuller, 1979) and Phillips–

Perron (PP) test (Phillips and Perron, 1988). The unit root tests are grounded on the following

three regression forms:

Table (5.2) Different Regression Forms of Unit Root Test

Without Constant (Intercept) and trend	$\Delta Y_t = \delta Y_{t-1} + u_t$
With Constant (Intercept)	$\Delta Y_t = \alpha + \delta Y_{t-1} + u_t$
With constant (Intercept) and trend	$\Delta Y_t = \alpha + \beta T + \delta Y_{t-1} + u_t$

Source: Eduardo Rossi, "Unit Roots Tests", University of Pavia, (2014) accessed Jul 2, 2017

http://economia.unipv.it/pagp/pagine_personali/erossi/Econometria_Finanziaria

_2013/Rossi_unit_roots_Ec_Fin_2014.pdf

➢   **Unit Root Tests Hypotheses**

ADF and PP tests

❖   Null hypothesis H0 :δ=0 has Unit root (is not stationary)

❖   Alternative hypothesis H1: δ≠0 Unit root exists not (stationary)

Decision Rules

❖   If t* table > computed (t) for ADF, PP, KPSS ==> Accept null hypothesis.

❖   If t* table < computed (t) for ADF, PP, KPSS (t) ==> Reject null hypothesis.

        In case the series are not stationary in levels, usually the first difference is taken to

make the series stationary. In case of co-integration analysis, the unit root test helps

determine in which order the series subject of study are integrated e.g. I (0) in levels, or I (1)

in first difference and so on.

Table (5.3) Findings of the Unit Root Test

Variable	ADF		PP		Decision
	Constant	Const. & Trend	Constant	Const. &Trend	
E	-3.623716***	-4.198801***	-3.596515***	-4.128560**	Stationary
Y	-2.000819	-4.556184***	-0.921358	-1.576013	Non stationary
$(Y)^2$	-1.191930	-1.448763	-0.584293	-1.335865	Non stationary
ΔE	-9.350576***	-9.394838***	-10.75072 ***	-11.92258***	Non stationary
ΔY	-7.586408***	-7.556884***	-7.417438***	-7.383997***	Non stationary
$\Delta(Y)^2$	-6.188006***	-6.079498***	-6.390910***	-6.318032***	Non stationary

Source: Computed by the Author using Eviews08 software

From the table above is noticed that the first series E is stable at the level while the explanatory variables series are unstable at the level. They became stabilizes after taking the first differences.

➤ **Estimation Results of EKC Model using OLS estimation method**

The estimated model for air pollution and the economic growth in Algeria

Table (5.4) The Results of Estimating the EKC Model Using OLS method

Variables	Coefficients	t-Ratio	P-Value
C	-6.701782	-2.761046	0.0086***
Y	0.004589	3.423461	0.0014***
Y^2	-5.29E-07	-2.890197	0.0061***
Diagnostic test statistic			
R^2=0.507058		Mean dependent var.= 2.853752	
Adjusted R^2= 0.4830012		S.D. dependent var.= 0.606207	
S. E. of regression= 0.435874		Akaike info criterion= 1.242821	
Sum Squared resid. = 7.789446		Schwarz criterion = 1.364470	
Log-likelihood= -24,34206		Hannan-Quinn criter= 1.287934	
F- Statistic=21.08705		Durbin-Watson stat=1.127524	
Prob(F-statistic)=0.000001			

Source: Computed by researcher using Eviews 08 software.

Note: *, ** and *** represent 10%, 5% and 1% level of significance respectively.

From the above table, the estimated model using OLS method for environmental Kuznets curve for air pollution during the period 1970-2013 in Algeria can be written as follows:

$$E_t = -6.701782 + 0.004589Y_t - 0.000000529(Y_t)^2$$
$$R^2 = 0.5070580, \quad AdjR^2 = 0.4830012, \quad D.W = 1.127524, \quad F = 21.08705$$

(5.3)

5.2.2.2. The Statistical Tests

Through the obtained results, the discussion will start with the statistical tests. The model will be tested using statistical criteria. This aims to test the significance of the estimated parameters of the model. The test will be made through employing the t-statistic test, R^2 as well as the overall significance test of the model through the Fisher statistic.

➢ **t- Statistic test**

The comparison of the calculated *t* ratio with the critical value is necessary to conduct an objective or a significance test for β_i

$$df = (n - k) = 44 - 3 = 41$$
(5.4)

n is observations number,

k is the number of estimated parameters

$$t_{n-k}^{\alpha} = t_{41}^{0.05} = 2.021\,[1]$$
(5.5)

Otherwise, the most widely accepted cutoff point is 0.05, and the test is said to be significant at the 0.05 level if the P-value ≤ 0.05. Here the acceptance or the rejection of the null hypothesis will be based on the t-statistic and it's P-value.

In the estimated model, it is hypothesized that:

$H_0: \beta_0=0, \quad H_1: \beta_0 \neq 0$

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[1] Dominick Salvatore, *Managerial Economics*, 588.

H_0: $\beta_1 = 0$, H_1: $\beta_1 \neq 0$

H_0: $\beta_2 = 0$, H_1: $\beta_2 \neq 0$

That is under the null hypothesis, the economic growth represented by the GDP per capita and GDP per capita squared have no effects whatsoever on the air pollution denoted by CO_2 emissions per capita. From the table 5.4, it is noted that all the calculated *t* values are greater than the *t* table value which was 2.021. In addition to that, the P-values are less than 5% for all estimated parameters. Thus, the null hypothesis can be rejected based on the fact that the economic growth has an effect on the air pollution in Algeria.

➢   **The Coefficient of Determination R Squared**

The coefficient of determination R squared is defined as a measurement of the goodness of fit of the fitted sample regression line, which means if the data points were to fall on regression line, all the variation in the dependent variable would be explained by the variation in the explanatory variables[1]. That is, it gives the proportion or percentage of the total variation in the dependent variable explained by independent variables.

$$R^2 = \frac{\exp lained \ \text{variation in} Y}{total \ \text{variation in} \ Y} = \frac{\sum (\hat{Y}_t - \bar{Y})^2}{\sum (Y_t - \bar{Y})^2} \qquad (5.6)$$

The value of the coefficient of determination *R* squared for the estimated EKC model was 0.507058, which means that the air pollution and precisely the CO_2 emissions in Algeria are explained by the economic growth. This is merely acceptable since the income is the only explanatory variable included in this model. The reaming 50% unexplained is interpreted by other variables.

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[1] Ibid., 134.

➢ **The Analysis of Variance**

The overall explanatory power of the entire regression can be tested with the analysis of variance. This uses the value of *F statistic,* or F ratio. The F statistic is used to test the hypothesis that the variation in the independent variables GDP and DGP^2 explains a significant proportion of the variation in the dependent variable CO_2. Thus, the F statistic can be used to test the null hypothesis that they are not equal to zero.

The value of F statistic is given by:

$$F = \frac{\text{explained variation}/(k-1)}{un\exp lained \text{ variation}/(n-k)} \qquad (5.7)$$

n indicates the number of observations

k indicates the number of estimated parameters.

We can also calculate the F statistic in terms of the coefficient of determination as in:

$$F = \frac{R^2/(k-1)}{(1-R^2)/(n-k)} \qquad (5.8)$$

The aims of the F analysis is to test the overall significance of the regression via two hypotheses:

The null hypothesis stands to reject the relationship between the explanatory variable and the dependent variable.

H_0: $b_0 = b_1 = b_2 = 0$

The alternative hypothesis contends that at least one of the parameters involved in the model is not equal to zero.

H_0: $b_1 \neq 0$

Conducting the F test or analysis of variance necessitates the comparison between the calculated value of F statistic $F_{cal} = 21.08$ and the critical value from the table of F distribution for the 5% level of significance.

$$df_1 = k = 3 \tag{5.9}$$

$$df_2 = n - k = 44 - 3 - 1 = 40 \tag{5.10}$$

Thus, the table value of F statistic is[1]:

$$F^k_{n-k-1} = F^3_{40} = 2.84 \tag{5.11}$$

The alternative hypothesis is accepted at the 5% level of significance and not all coefficients are equal to zero because the calculated value of the F statistic of 21.08 exceeds the critical value (table value) of 2.84.

❖ **Diagnostic Tests**

After the statistical testing of the estimated model, it will undergo the testing of the main regression problems, like multicollinearity, heteroscedasticity, normal distribution for residuals and the Durbin Watsons test for autocorrelation of errors.

➤ **Heteroscedasticity**

The basic fundamental assumption in the ordinary least square estimation method is that the variance of error term is constant for all the values of the explanatory variables, and the heteroscedasticity problem occurs when this assumption is disrupted.

There are various methods to test the heteroscedasticity problem. Amongst these, there is the Breusch pagan Godfrey test, which tests the heteroscedasticity by taking the value of (Obs.*R^2) and comparing it to the value of Chi square value at 5% significance level,

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[1] Ibid., 589.

considering a degree of freedom that is equal to the number of parameters minus the constant parameter.

✓   Null Hypothesis: There is no Heteroscedasticity problem.

✓   Alternative Hypothesis: There is a Heteroscedasticity problem.

In case the Chi squared X^2 table value is greater than (Obs*R^2), the null hypothesis is accepted, but, contrarily, if the (Obs*R^2) is greater than X^2, the null hypothesis is automatically rejected, and then this will be a problem of heteroscedasticity. The table 5.5 below demonstrates the results.

Table (5.5) Results of Breusch Pagan Godfrey Heteroscedasticity Test

F-statistic	2.025956	Prob. F(2,41)	0.1449
Obs*R-squared	3.957305	Prob. Chi-Square(2)	0.1383
Scaled explained SS	3.075823	Prob. Chi-Square(2)	0.2148

Source: Computed by researcher using Eviews 08 software.

The obtained results clarify vividly that the value of Obs* R^2 = 3.95, which is smaller than the table value of $X^2_{0.05}$ (2)= 5.99. The null hypothesis is, thus, accepted, and consequently there is no heteroscedasticity problem in the estimated model.

➢   **Normality Test of Residuals**

The next figure shows the normality distribution test for residuals using Jarque-Bera test.

❖   The null hypothesis: the residuals are normally distributed.

❖   The alternative hypothesis: the residuals are not normally distributed.
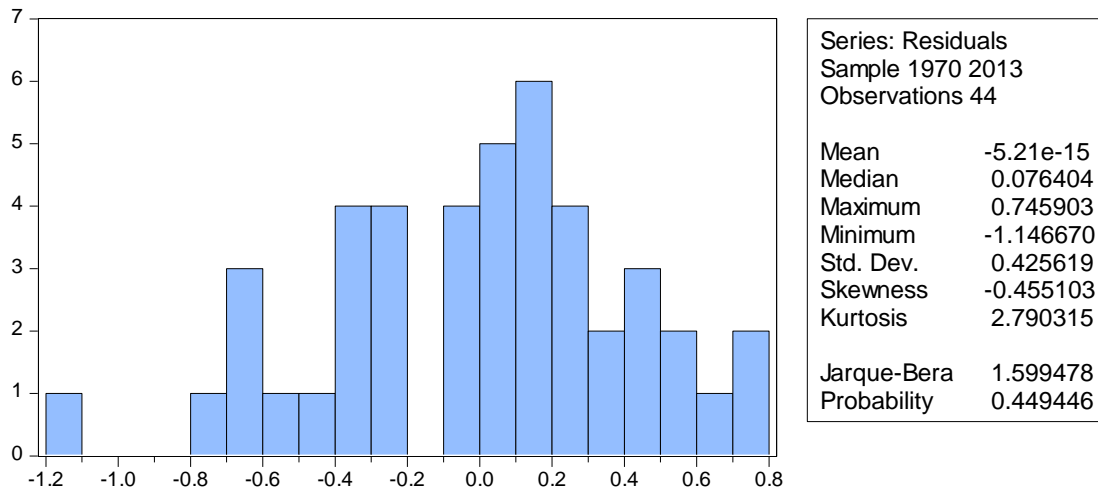
Figure (5.3): Normality Distribution for Residuals

Source: Computed by researcher using Eviews 08 software.

The Jarque-Bera value in the chart 5.3 above is equal to 1.599478 and is less than the table chi squared $\mathbf{X^2_{0.05}(2)}$ =5.99, which is justified by the p-value more than 5%. This means that the residuals are normally distributed.
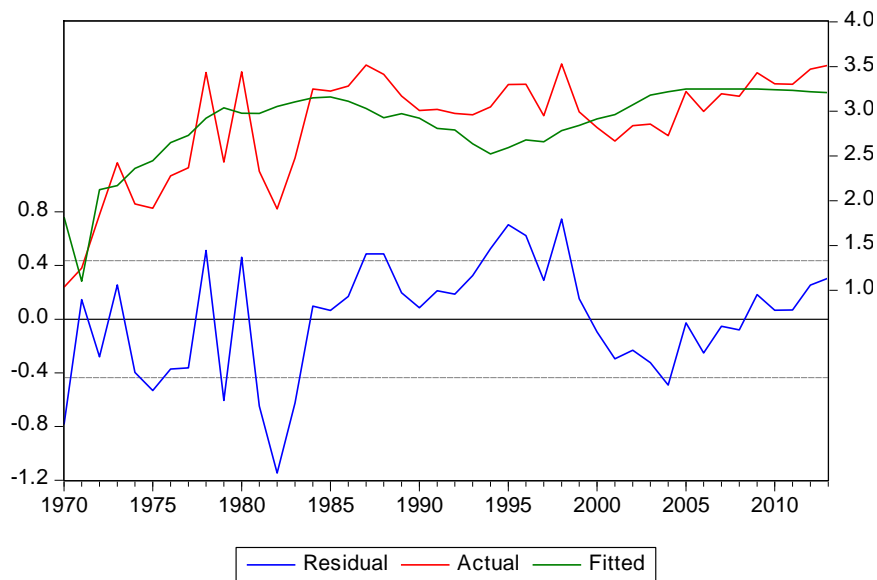
Figure (5.4): The actual and Estimated Models

Source: Computed by researcher using Eviews 08 software.

➤   **Autocorrelation Test**

Autocorrelation or serial correlation occurs whenever consecutive errors or residuals are correlated. If the consecutive errors have a similar sign, then the result is a positive auto correlation, but alternatively, if they change signs frequently then the result would be a negative autocorrelation. Autocorrelation can be identified by using the Durbin Watson statistic (d).

$$d = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n}(e_t)^2} \qquad (5.12)$$

e_t and e_{t-1} refer to the error term in period t and in the precedent period (t-1) respectively. The value of d ranges between 0 and 4.

Positive autocorrelation	Inconclusive	No autocorrelation	Inconclusive	Negative autocorrelation

0   d_L d_U 4-d_U 4-d_L 4
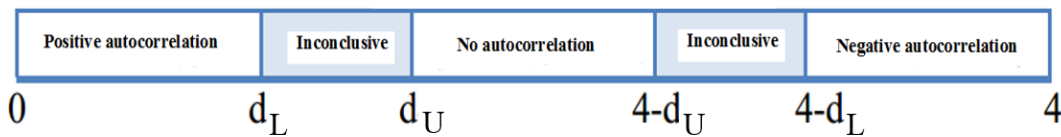
The lower d_L and upper d_U points are obtained from the Durbin-Watson tables in order to decide about Durbin-Watsons test.

When:

$d_{cal} \prec d_L$ the null hypothesis of no positive correlation is rejected.

$d_L \leq d_{cal} \leq d_U$ No decision.

$d_U < d_{cal} < 4 - d_U$ the null hypothesis of no positive or negative autocorrelation is not rejected.

$4 - d_L \prec d \prec 4 - d_U$ No decision

$d_{cal} \succ 4 - d_L$ the null hypothesis of no negative autocorrelation is rejected.

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In this way, the calculated Durbin-Watson value is compared to the table value n = 44 and k = 2.

$$D.W_{cal} = 1.127523 < D.W_{tab} = (d_L = 1.39, d_U = 1.60). \tag{5.13}$$

Therefore, the model is suffering from the autocorrelation between the errors since the null hypothesis of the positive autocorrelation between the errors is accepted.

5.3.   The Estimation of EKC Using the FR Tanaka Method

The classical regression is grounded on the principles of statistics and the FR model is referred to as a fuzzy or possibilistic model of classical regression. M. Hadi Mashinchi states that, "It has been observed that the FR model is more effective than the classical regression when the normality of error terms and dependent variables, and the availability of a sufficiently large data set (complete data conditions) are not satisfied"[1]. In those cases, we can use the FR model on the dependent and the independent variables in a particular system in order to examine the inexact relationship existing between them, which is estimated through minimizing the criteria of errors.

5.3.1.   The Methodological Approach of the FR Tanaka Method

The fuzzy model applied follows the Tanaka (1982) fuzzy regression method, wherein the output and the parameters are handled as fuzzy numbers while the inputs are crisp data. The fundament of the Tanaka (1982) fuzzy regression method is minimizing fuzziness in order for the model to fit. By transferring the problem into a linear programming problem, the objective function is to minimize the complete range of the fuzzy numbers. The fuzzy environmental Kuznets Curve depending on the Tanaka method generally takes the form:

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[1] M. Hadi Mashinchi. "Fuzzy Linear Regression With Global Continuous Optimization", PhD Dissertation, Faculty of Science, Department of Computing, Macquarie University, 2012, 40.

$$\tilde{E} = \tilde{\beta}_0 + \tilde{\beta}_1 Y_1 + \tilde{\beta}_2 Y_1^2 \qquad (5.14)$$

Where:

$\tilde{E}$ indicates the fuzzy output primarily the CO_2 emissions per capita.

Y_1, Y_1^2 Indicate the crisp input for GDP pc and $(GDPpc)^2$ consecutively.

$\tilde{\beta}_i, i = 0,1,2$ indicates the fuzzy coefficients demonstrated in the form of symmetric triangular

fuzzy numbers represented by $\tilde{\beta}_i = \langle c_i, s_i \rangle$, wherein s_i and c_i consecutively indicate the

spread and the center of the STFN which represent the estimated parameters $\tilde{\beta}_0, \tilde{\beta}_1, \tilde{\beta}_2$ with

a function of membership designed as:

$$u_{\tilde{\beta}_i}(Y) = \begin{cases} 1 - \dfrac{|Y - c_i|}{s_i} & \text{when } c_i - s_i \leq Y \leq c_i + s_i \\ 0 & \text{Otherwise,} \end{cases} \qquad (5.15)$$

Thus, the function (5.9) can be formulated as:

$$\tilde{E} = \langle c_0, s_0 \rangle + \langle c_1, s_1 \rangle Y_1 + \langle c_2, s_2 \rangle Y_1^2 \qquad (5.16)$$

After estimating $\tilde{\beta}_i = \langle c_i, s_i \rangle$ for all $i \in N_n$, it becomes easier to confirm by means of

the extension principle that $\tilde{E}$ in (5.12) is also a symmetric triangular fuzzy number given by

$$\tilde{E}(E) = \begin{cases} 1 - \dfrac{|E - Y^T c|}{s^T |Y|} & \text{when } Y \neq 0 \\ 1 & \text{when } Y = 0, E \neq 0 \end{cases} \qquad (5.17)$$

For all $Y \in IR$ where

$\tilde{E}_i^{h=1}$ represents the center related to the membership function for a SFTN

$\tilde{E}_i^{h=1} = \overline{\tilde{E}}_i = (\tilde{E}_i^U + \tilde{E}_i^L)/2$. Based on the perspective of regression, it can be clear that

$\tilde{E}_i^U - E_i$ and $E_i - \tilde{E}_i^L$ are components of the total sum of squares SST that equal SSR+SSE,

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$E_i - \tilde{E}_i^{h=1}$ are the components of a sum of squares of error SSE, whereas $\tilde{E}_i^U - \tilde{E}_i^{h=1}$,

$\tilde{E}_i^{h=1} - \tilde{E}_i^L$ are components of the sum of squares regression. SSR is the sum of the squared

differences between the population mean and the prediction for each observation[1].

The objective function in terms of the classical linear programming problem can take

the form:

$$\text{minimize} \sum_{j=1}^{44} s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|$$

subject to

$$(c_0 + c_1 x_{1j} + c_2 x_{2j}) - (s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|) \leq Y_j \qquad (5.18)$$

$$(c_0 + c_1 x_{1j} + c_2 x_{2j}) + (s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|) \geq Y_j$$

$$s_i \geq 0, \ i = 0,1,2, \ j = 1,2,...44$$

In this investigation, there are 44+44+3+3 constraints' equations. This can be

designed as follows:

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[1] Arnold F., Shapiro, "Fuzzy Regression Models", 5.

Var $s_0 >= 0$

Var $s_1 >= 0$

Var $s_2 >= 0$

Minimize $44 * s_0 + 160461.73061 * s_1 + 597173128.93 * s_2$

Constraint $c[1]: c_0 + 2692.633111 * c_1 + 7250273.071 * c_2$
$- s_0 - 2692.633111 * s_1 - 7250273.071 * s_2 <= 1.0360$

Constraint $c[2]: c_0 + 2322.1 * c_1 + 5392148.41 * c_2$
$- s_0 - 2322.1 * s_1 - 5392148.41 * s_2 <= 1.2479$

Constraint $c[3]: c_0 + 2878.6 * c_1 + 8286337.96 * c_2$
$- s_0 - 2878.6 * s_1 - 8286337.96 * s_2 <= 1.8436$

Constraint $c[4]: c_0 + 2907.6 * c_1 + 8454137.76 * c_2$
$- s_0 - 2907.6 * s_1 - 8454137.76 * s_2 <= 2.4242$

Constraint $c[5]: c_0 + 3040.4 * c_1 + 9244032.16 * c_2$
$- s_0 - 3040.4 * s_1 - 9244032.16 * s_2 <= 1.9638$

Constraint $c[6]: c_0 + 3105.5 * c_1 + 9644130.25 * c_2$
$- s_0 - 3105.5 * s_1 - 9644130.25 * s_2 <= 1.917$

Constraint $c[7]: c_0 + 3271.7 * c_1 + 10704020.89 * c_2$
$- s_0 - 3271.7 * s_1 - 10704020.89 * s_2 <= 2.2787$

Constraint $c[8]: c_0 + 3346.4 * c_1 + 11198392.96 * c_2$
$- s_0 - 3346.4 * s_1 - 11198392.96 * s_2 <= 2.3681$

Constraint $c[9]: c_0 + 3550 * c_1 + 12602500 * c_2$
$- s_0 - 3550 * s_1 + 12602500 * s_2 <= 3,4334$

(5.19)

Constraint $c[10]: c_0 + 3703,9 * c_1 + 13718875,21 * c_2$
$- s_0 - 3703,9 * s_1 + 13718875,21 * s_2 <= 2,4317$

Constraint $c[44]: c_0 + 4617,5 * c_1 + 21321306,25 * c_2$
$- s_0 - 4617,5 * s_1 + 21321306,25 * s_2 <= 3,5148$

Constraint c1[1]: $c_0 + 2692.633111 * c_1 + 7250273.071 * c_2$
$- s_0 - 2692.633111 * s_1 - 7250273.071 * s_2 >= 1.0360$

Constraint c1[2]: $c_0 + 2322.1 * c_1 + 5392148.41 * c_2$
$- s_0 - 2322.1 * s_1 - 5392148.41 * s_2 >= 1.2479$

Constraint c1[3]: $c_0 + 2878.6 * c_1 + 8286337.96 * c_2$
$- s_0 - 2878.6 * s_1 - 8286337.96 * s_2 >= 1.8436$

Constraint c1[4]: $c_0 + 2907.6 * c_1 + 8454137.76 * c_2$
$- s_0 - 2907.6 * s_1 - 8454137.76 * s_2 >= 2.4242$

Constraint c1[5]: $c_0 + 3040.4 * c_1 + 9244032.16 * c_2$
$- s_0 - 3040.4 * s_1 - 9244032.16 * s_2 >= 1.9638$

Constraint c1[6]: $c_0 + 3105.5 * c_1 + 9644130.25 * c_2$
$- s_0 - 3105.5 * s_1 - 9644130.25 * s_2 >= 1.917$

Constraint c1[7]: $c_0 + 3271.7 * c_1 + 10704020.89 * c_2$
$- s_0 - 3271.7 * s_1 - 10704020.89 * s_2 >= 2.2787$

Constraint c1[8]: $c_0 + 3346.4 * c_1 + 11198392.96 * c_2$
$- s_0 - 3346.4 * s_1 - 11198392.96 * s_2 >= 2.3681$

Constraint c1[9]: $c_0 + 3550 * c_1 + 12602500 * c_2$
$- s_0 - 3550 * s_1 + 12602500 * s_2 >= 3,4334$

Constraint c1[10]: $c_0 + 3703,9 * c_1 + 13718875,21 * c_2$
$- s_0 - 3703,9 * s_1 + 13718875,21 * s_2 >= 2,4317$

Constraint c1[44]: $c_0 + 4617,5 * c_1 + 21321306,25 * c_2$ (5.20)
$- s_0 - 4617,5 * s_1 + 21321306,25 * s_2 >= 3,5148$

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5.3.2.   The Empirical Results and Their Statistical Tests

The next session includes the empirical results and statistical tests for the estimated model of the environmental Kuznets Curve of air pollution in Algeria by using the Tanaka method for fuzzy regression.

5.3.2.1.   The Empirical Results

The SAS-Proc LP 09 software is used in order to solve this linear problem. The estimated model with interval coefficients was achieved as follows:

Table (5.6): The results of estimating the EKC coefficients using FR Tanaka method

Variable	Coefficients	Stand. Error	t Value	Pr>|t|
Intercept	<-5.7191964 ; 0.88742>	0.88742	-11.8023481	0.000
Y_1	<0.0042803; 0>	0.000267632	15.9932016	0.000
Y_1^2	<-0.0000005; 0>	3.65492E-08	-13.6802062	0.000
R^2	0.3866			
F- statistic	12.92250402			
Prob (F-statistic)	0.000000			

Source: computed by the researcher using SAS-Proc LP 09 software.

The EKC obtained model for air pollution in Algeria can be written as follows:

$$\tilde{E}_i = \langle -5.7191964 \quad 0.88742 \rangle + \langle 0.0042803 \quad 0 \rangle Y_i + \langle -0,0000005 \quad 0 \rangle Y_i^2 \qquad (5.21)$$

5.3.2.2.   The Statistical Tests

The statistical tests will be done through using the t-statistic test, R^2 in addition to the overall significance test of the model through the F statistic of Fisher.

➢   **t- Statistic test**

The **t** test for the estimated coefficients will be taken by comparing the calculated t with the table one below with a degree of freedom equal to:

$$df = (n - k) = 44 - 3 = 41 \qquad (5.22)$$

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n is observations number,

k is the number of estimated parameters

$$t_{n-k}^{\alpha} = t_{41}^{0.05} = 2.021 \,[1]$$ (5.23)

It is clear from the table 5.6 that all the t-statistics values for the estimated coefficients are greater than the critical ones. This is also proved by the P-values which are less than 5%. Thus, the estimated model passed successfully the t-test with high significance.

➢ **The Coefficient of Determination R Squared**

The R squared value was obtained by using its formula in the MS Excel 2013. Its value is 38.66% which means that the GDP per capita can explain 38.66% of the changes in the Carbon Dioxide (CO_2) emissions per capita in Algeria. This is acceptable because of the fact that the income is the only explanatory variable included in the model. The rest 61.34% can be explained by other vector variables.

➢ **The Analysis of Variance**

The table 5.6 shows the calculated value for F-statistic which $F_{cal} = 12.92$. The latter will be compared with the table value of F-statistic at 5% level of significance with a degree of freedom equal to:

$$df_1 = k - 1 = 3 - 1 = 2$$ (5.24)

$$df_2 = n - k = 44 - 3 = 41$$ (5.25)

Thus, the table value of F statistic is[2]:

$$F_{0.05}{}^{k}{}_{n-k-1} = F_{41}^{2} = 3.23$$ (5.26)

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[1] Dominick Salvatore, *Managerial Economics*, 588.
[2] Ibid., 589.

Therefore, the calculated F- statistic is greater than the table value of F-statistic. This means that the estimated regression model is statistically significant

5.4. Fuzzy Least Square Regression

Diamond (1997) proposed the most utilized methodology of fuzzy linear regression analysis (FLSR) by using distance measure[1]. The formulation of fuzzy least squares linear regression is as follows:

$$\min \sum D(\langle c_1, s_{1L}, s_{1R} \rangle, \langle c_2, s_{2L}, s_{2R} \rangle)^2 \tag{5.27}$$

$$D(\langle c_1, s_{1L}, s_{1R} \rangle, \langle c_2, s_{2L}, s_{2R} \rangle)^2 = (c_1 - c_2)^2 + ((c_1 - s_{1L}) - (c_2 - s_{2L}))^2 + ((c_1 + s_{1R}) - (c_2 + s_{2R}))^2 \tag{5.28}$$

The fuzzy least square regression provides a measure of distance indicated by D between two TFNs based on their centers represented by c_i, left spread and right spread denoted by s_{iL} and s_{iR} respectively.

The main idea in least square fuzzy linear regression analysis is to seek the optimized coefficients in fuzzy linear regression, which minimizes the defined distance measure for observed and predicted data. Based on the chosen distance measure, and the type of the fuzzy input or output.

5.4.1. The FLSR Methodological Approach to Estimate the EKC Model

This section includes the estimation of the environmental Kuznets Curve in Algeria for air pollution from 1970 to 2013 using the fuzzy least square estimation method. That is by assuming fuzzification rates for the input data, in order to render them fuzzy variables. These fuzzification rates indicate the measurement errors, and thus, the evaluation of the estimated models will be according to 1%, 2% and 5% fuzzification rates.

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[1] M. Hadi Mashinchi. "Fuzzy Linear Regression with Global Continuous Optimization", 44.

5.4.2. The Empirical Results for EKC Using FLSR Method and the Statistical Test

In the next part, the estimation of the Environmental Kuznets Curve for air pollution in Algeria during the period 1970-2013 will be predicted by employing the Fuzzy Least Square Regression method, and then it will be tested for good fit of the estimated model.

5.4.2.1.   The Empirical Results for EKC Using FLSR Method

The empirical results are obtained for each of the three fuzzification rates at 1%, 2% and 5%.

➢   **The Estimated EKC Model at 1% level of Fuzzification**

By means of the Matlab 2012 software, the matrices resulting from the application of the fuzzy least square method in this case are:

$$E = \begin{pmatrix} 1.0257 \\ 1.2354 \\ \vdots \\ 3.4796 \end{pmatrix}, \quad F = \begin{pmatrix} 1.0257 \\ 1.2354 \\ \vdots \\ 3.5499 \end{pmatrix}$$

$$C = \begin{pmatrix} 1 & 2665.70678 & 7177770.34 \\ 1 & 2298.84573 & 5338072.4 \\ \vdots & \vdots & \vdots \\ 1 & 4571.33595 & 21108194.4 \end{pmatrix}, \quad F = \begin{pmatrix} 1 & 2719.55944 & 7322775.8 \\ 1 & 2345.28705 & 5445912.25 \\ \vdots & \vdots & \vdots \\ 1 & 4663.68618 & 21534622.5 \end{pmatrix}$$

(5.29)

Where:

E represents the matrix of the maximum values of the dependent variable

F indicates the matrix of the minimum values of the dependent variable

C represents the matrix of the maximum values of the independent variables

D denotes the matrix of the minimum values the independent variables

The resulting matrices were achieved by using the triangular membership functions, based on the fuzzification rate of 1%, and thus, the fuzzy model was estimated as follows:

$$\tilde{E} = (-6.14339803) + (0.0043)\tilde{Y}_1 + (-4.8775e-07)\tilde{Y}_2 \tag{5.30}$$

➢   **The Estimated EKC Model at 2% Level of Fuzzification**

The matrices resulting from the application of the fuzzy least square method at 2%

level of fuzzification are:

$$E = \begin{pmatrix} 1.0154 \\ 1.2229 \\ \vdots \\ 3.4445 \end{pmatrix}, \quad F = \begin{pmatrix} 1.0568 \\ 1.2729 \\ \vdots \\ 3.5851 \end{pmatrix}$$

$$C = \begin{pmatrix} 1 & 2638.78045 & 7105267.61 \\ 1 & 2275.62506 & 5284152.48 \\ \vdots & \vdots & \vdots \\ 1 & 4525.16084 & 20894980.3 \end{pmatrix}, \quad F = \begin{pmatrix} 1 & 2746.48577 & 7395278.53 \\ 1 & 2368.50772 & 5499832.17 \\ \vdots & \vdots & \vdots \\ 1 & 4709.86129 & 21747836.6 \end{pmatrix}$$

(5.31)

The resulting matrices were achieved by using the triangular membership functions,

based on the fuzzification rate of 2%, and thus, the fuzzy model was estimated as follows:

$$\widetilde{E} = (-4.91515194) + (0.00360684)\widetilde{Y}_1 + (-3.97\mathrm{e}-07)\widetilde{Y}_2 \qquad (5.32)$$

➢   **The Estimated EKC model at 5% level of Fuzzification**

The matrices resulting from the application of the fuzzy least square method at 5%

level of fuzzification are:

$$E = \begin{pmatrix} 0.984 \\ 1.1855 \\ \vdots \\ 3.339 \end{pmatrix}, \quad F = \begin{pmatrix} 1.088 \\ 1.3103 \\ \vdots \\ 3.6905 \end{pmatrix}$$

$$C = \begin{pmatrix} 1 & 2638.78045 & 7105267.61 \\ 1 & 2275.62506 & 5284152.48 \\ \vdots & \vdots & \vdots \\ 1 & 4525.16084 & 20894980.3 \end{pmatrix}, \quad F = \begin{pmatrix} 1 & 2827.26477 & 7612786.72 \\ 1 & 2438.16971 & 5661591.94 \\ \vdots & \vdots & \vdots \\ 1 & 4848.38662 & 22387478.9 \end{pmatrix}$$

(5.33)

The resulting matrices were achieved by using the triangular membership functions,

based on the fuzzification rate of 5%, and thus, the fuzzy model was estimated as follows:

Table (5.7): The results of estimating the EKC coefficients FLSR at 5% fuzzification

Variable	Parameter Estimate	Standard Error	t Value	Pr>|t|
Intercept	-2.05031176	1.964579	-2.50188547	0.000
Y_1	<0.0020136, 0>	0.00108503	3.32418472	0.000
Y_2	<-1.84E-07, 0>	1,48177E-07	-2.67923135	0.000
R^2	57.52			
F- statistic	27.761728			
Prob(F-statistic)	0.00000			

Source: Computed by the Researcher Using Matlab 2012 software.

$$\tilde{E} = \left(-2.0503117\right) + \left(0.00203136\right)\tilde{Y}_1 + \left(-1.84e-07\right)\tilde{Y}_2$$

(5.34)

The above estimation results clarify vividly the following conclusions deduced from the application of the ordinary least square method:

• There exists an inverse relationship between the fuzzification rate and the average absolute error value,

• There exists an inverse relationship between the fuzzification rate and the parameters of the estimated model,

• The fuzzification rate affects the signs of the parameters of the estimated model, and consequently, in the economic test.

5.4.2.1. The Statistical Tests

These statistical tests will be only done for the estimated model of FLSR of 5% fuzzification, due to the fact that the more the fuzzification level increases, the more the error

decreases, a fact which is proved by the MAPE as we will discuss later. Thus, we will perform

it using the t-statistic test, the R^2 and the F- statistic of Fisher test.

➤   **t- Statistic test**

As for this test the calculated t student value will be compared with the table one at 5%

significance level.

$$t_{n-k}^{\alpha} = t_{41}^{0.05} = 2.021\,[1] \tag{5.35}$$

It is clear from the table 5.7 that all the t-statistics values for the estimated coefficients

are greater than the critical ones which means that the model passed this test successfully.

➤   **The Coefficient of Determination R Squared**

The R squared value was obtained by using its formula in the MS Excel 2013. Its

value is 57.52% which means that the GDP per capita can explain 57% of the changes in the

Carbon Dioxide (CO_2) emissions per capita in Algeria and the rest 43% can be explained by

other explanatory variables.

➤   **The Analysis of Variance**

The table 5.7 shows the calculated value for F-statistic which $F_{cal} = 27.76$.

$$F_{0.05}{}^{k}{}_{n\text{-}k\text{-}1} = F_{41}^{2} = 3.23 \tag{5.36}$$

Therefore, the calculated F- statistic is greater than the table value of F-statistic. This

means that the estimated regression model is statistically significant.

5.5.   The Comparison of the Estimated Models and the Economic Results' Discussion

In this section, the comparison between the estimated models by different estimation

method will be done in addition to the economic discussion of the results.

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[1] Dominick Salvatore, *Managerial Economics*, 588.

5.5.1. Comparison between the Used Estimation Methods

The estimated models used for Environmental Kuznets Curve for Air pollution in Algeria during the period 1970-2013, were obtained based on the OLS, FR for Tanaka and FLSR methods. In order to compare the estimation quality of different estimated models we used the Mean Absolute percentage Error (MAPE) and the Income Turning Points (ITP).

➢   **The Mean of Absolute Percentage Error MAPE**: It can be referred to as the MAPE, which is also known as the MAPD, which stands for the mean absolute percentage deviation, and it is a standard used to assess how far the forecasting methods are accurate and how good their estimation quality is[1]. Its formula is addressed as follows:

$$\left(\frac{1}{n} \sum \frac{|Actual - Estemated|}{|Actual|} \right) \times 100 \qquad (5.37)$$

Table (5.8): A Comparison between the used estimating methods

	B1	B2	ITP	MAPE
OLS	0.004589	-0.000000529	4337.429112	13.96594
TANAKA	0.0042803	-0.0000005	4280.3	1. 158459
FLSR 1%	0.0043	-4.88E-07	4407.9959	4.891
FLSR 2%	0.00360684	-3.97E-07	4542.619647	4.093
FLSR 5%	0.0020136	-1.84E-07	3545.070423	3.764

Source: Computed by the researcher.

The Mean Absolute Percentage Error (MAPE) recorded different results for the various estimation methods, where the worst value for it was the one of the OLS model with 13.96, which means that, the estimated values are quite far from the actual values. While the

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[1] Arther V. Hill. *The Encyclopedia of Operations Management.* (USA: Pearson education Inc., 2012), 220.

fuzzy regression method for Tanaka gets the best value for the MAPE, which is equal to 1.1584. That means that the Tanaka estimated values are the best and the closest to the real values. In addition to that, it is noted that the more the fuzzification level of the FLSR increases, the more the error results in the MAPE value decrease. While the fuzzification level increased to 1%, 2% and 5%, the MAPE results decreased to 4.891, 4.093 and 3.764 respectively. Thus, The Tanaka model is recognized as the best model in reducing the estimation error compared to the OLS and FLSR estimation methods.

➢   **The Income Turning point (ITP)**: It is the level of the turning point of the income which sets the mark of the maximum of the emissions or concentrations. It can be found using the following formula:

$$\tau = -\beta_1 / 2\beta_2 \tag{5.38}$$

The computed turning points are for different estimated methods range inside the inside the interval [3500, 4500] in constant 2000 USD.
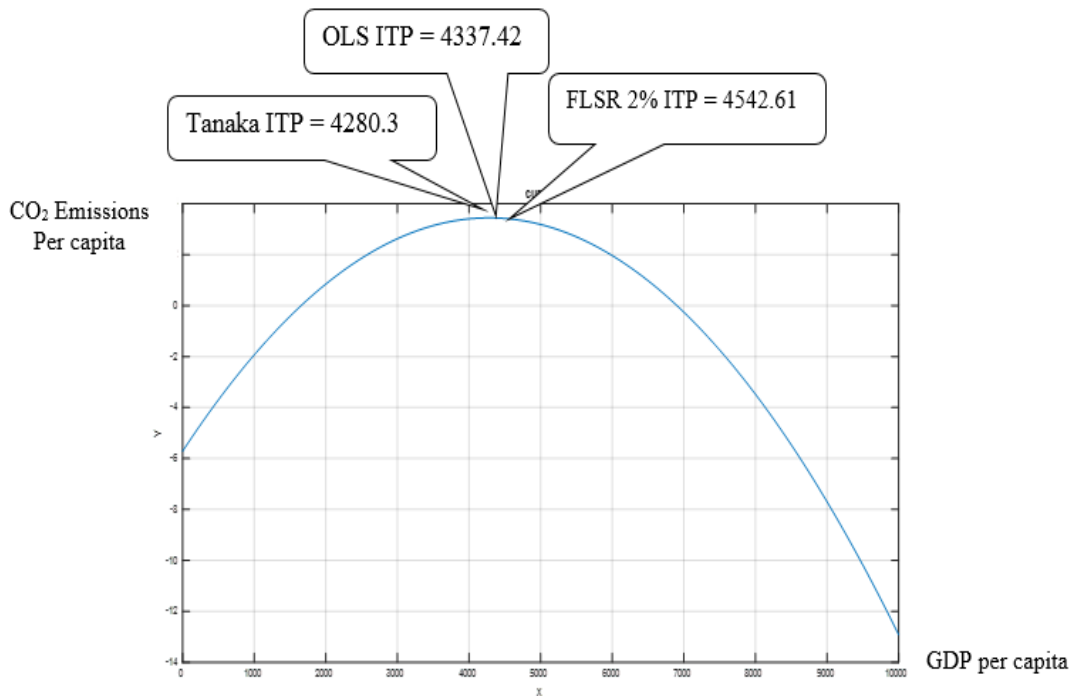

Figure (5.4) Environmental Kuznets curve for air pollution in Algeria

Source: Computed by the researcher

The calculated income turning points for CO_2 using the different estimation methods were found inside the used data set for the period 1970-2013. In 2012, Algeria reached the highest turning point 4542.61, which was calculated from the FLSR 2% model parameters. This empirical evidence is similar to the findings of the studies of Behnaz Saboori (2012)[1] in Malaysia, Fodha and Zaghdoud (2010) in Tunisia[2], Iwata et al. (2010) [3]in France, which also found the EKC's turning point within their observed sample period. In contrast, Abdul Jalil and Mahmud (2009) [4]in China, found the EKC's turning point outside the observed sample period.

5.5.2.   Economic Results Discussion

In line with the hypothesis of the environmental Kuznets curve, there is an inverted-U shaped relationship found between the per-capita GDP and per-capita pollutant emissions. This means that there is a certain point at which the economic growth can actually start to be advantageous for quality of the environment. According to the estimation results for each of the OLS, the fuzzy regression for Tanaka and the FLSR estimation methods, the results reveal that there is an inversed U-shaped relationship established between the environmental degradation represented by the CO_2 and per capita income in Algeria. This conclusion is based on the signs of the income variables ($\beta_1 > 0$, $\beta_2 < 0$), where the negative sign of the

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[1] Behnaz Saboori n, et al, "Economic growth and CO_2 emissions in Malaysia: A co-integration analysis of the Environmental Kuznets Curve", 190.

[2] Fodha, M., Zaghdoud, O, "Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental Kuznets curve", *Energy Policy*, Vol 38, (2010),1152 accessed Sep 15, 2016, http://www.sciencedirect.com/science/article/pii/S0301421509008301

[3] Iwata, H, Okada, K, and Samreth, S. "Empirical study on environmental Kuznets Curve for CO2 in France: the role of nuclear energy". Energy Policy, Vol 38, (2010), 4060, accessed Sep 3, 2016, https://econpapers.repec.org/paper/pramprapa/18997.htm.

[4] Abdul Jalil, Syed F.Mahmud,2009. EnvironmentKuznetscurveforCO2 emissions: A co-integration analysis for China, Energy Policy Vol 37, 5170, accessed Jun 15th , 2016, http://www.sciencedirect.com/science/article/pii/S0301421509005527

squared term seems to corroborate the delinking of both the CO_2 emissions and the real GDP

at the higher level of income. The empirical findings, then, support the validity of an inverted

U-shaped EKC for environmental degradation represented by CO_2 for air pollution in

Algeria. This result is consistent with the findings of Behnaz Saboori (2012)[1] in Malaysia,

Fodha and Zaghdoud (2010) in Tunisia[2], Abdul Jalil and Mahmud (2009) in China[3], Pao

and Tsai (2011) in Brazil[4].

In the case of Algeria, passing the income turning point does not necessarily prove

that Algeria reached the third industry in its economic development path, or that the income

per capita is quite high that it allows the people to care about the environmental situation.

Instead, this reduction in the levels of CO_2 emissions is due to the legislation intervention of

the Algerian government to limit the increase in the levels of this pollutant. This limited the

Algerian industrial investment, because Algeria is a member of Kyoto protocol to reduce

GHG gases, and that urged the Algerian government to issue laws and undertake some

procedures in the favor of reducing the GHG gases. This did not leave a chance for the

automatic effect of the economic growth to improve the environment as the EKC hypothesis

for income elasticity assumed (see chapter 2). Since the hydrocarbons sector is the backbone

of the Algerian economy, the national biggest stat owning company Sonatrach invested $100

million to store CO_2 geologically. A Joint Industry Project (JIP) became a subsequently set

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[1]Behnaz Saboori n, et al, "Economic growth andCO2 emissions in Malaysia: A co-integration analysis of the Environmental Kuznets Curve", 190.

[2] Fodha, M., Zaghdoud, " Economic growth and environmental degradation in Tunisia: an empirical analysis of the environmental Kuznets curve", 1156.

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up between the original partners British petroleum (BP) and Sonatrach. The town of In Salah

has been recognized by the Carbon Sequestration Leadership Forum as one of the most

important (Carbon capture and storage CCS) initiatives in the world, with more than three

million tons of CO_2 securely stored so far[1].

The income turning point was relatively low; a fact which could be predictable for

Algeria because it is still a developing country and its income is relatively low compared to

the developed countries. The Algerian government interventions help in protecting the

environment and seeking sustainable development, but it will consume a long time to offer

an environmental friendly industrial productive base, while the developed countries passed

with the polluted era in their first and second stage of economic growth path to reach the

third industry. This will push the Algerian economy and other developing economies,

especially the oil exporting economies, to skip a necessary phase in their economic path; the

phase which guarantees the production of their own machines for their local economy,

establishes their own experience in developing tools of their own to realize their self-

sufficiency, and to be able to export later easily to other nations. Instead, these economies

will stay dependent and constrained with those protocols. Accordingly, just as there was a

common responsibility for the sake of the environmental protection that urged the third world

countries to sacrifice an urgent phase that is a necessary fundament for their economic

growth, so there should be a common responsibility for the sake of the real protection of the

globe. These environmental conventions limit the developing countries more than the

developed countries since their economies are different. In order for these environmental

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[1] Carbon Capture and Sequestration Technologies. As of September 30, 2016, the Carbon Capture and Sequestration Technologies program at MIT has closed. The website is being kept online as a reference but will not be updated. In Salah Fact Sheet: Carbon Dioxide Capture and Storage Project. Accessed Mai 10th, 2016, https://sequestration.mit.edu/tools/projects/in_salah.html

conventions to be fair, the responsibility must also be shared form the side of the developed countries. They must share their experience in producing environmental friendly technology with the developing countries at low prices. Now that the independence has been achieved, it is high time for the countries to achieve an industrial productive base that allows them to equally compete in the world economy. The developed countries must at least share their environmental clean technology with the entire world as a step forward towards common responsibility of environmental protection. If denied, then these conventions set heavy limitations on the third world economic growth based on the pretext of environmental protection. Such conventions burdened the developing countries more than the developed countries, although they superficially seem as if caring to share the same responsibility, especially when pretending that they are on the same ship, whilst the developing countries belong economically to three different worlds.

Chapter Conclusion

This chapter contains the estimation of the environmental Kuznets curve in Algeria for the period 1970-2013 using various estimation methods, which are the Ordinary Least Square estimation method (OLS), the Tanaka model of fuzzy regression and the fuzzy least square regression (FLSR). There are many findings in this chapter, the main ones of which are based on the Algerian economy. First, all the estimated models have the correct signs for the estimated models, which means the EKC model for air pollution in Algeria has an inverted U-shaped relationship between the economic growth and environmental degradation. Second, the Tanaka method is superior to other estimation methods in the sense of reducing the errors. Third, the reduction of the $CO_{2\,pc}$ emissions as the GDP_{pc} increases was found to be due to the governmental interventions, which resulted in issuing laws in order to limit the polluted industries in the light of the environmental conventions that Algeria is a part of.

General Conclusion

General Conclusion

This study focuses revealing the relationship between the economic growth and the environmental degradation in Algeria, firstly through the indicator analysis and secondly by investigating the validity of EKC hypothesis for air pollution in Algeria during the period 1970-2013. These two processes were based on applying empirical studies using OLS, Fuzzy regression Tanaka method and Fuzzy least square estimation method. Several conclusions were drawn and they are as follows:

➢   The environmental problems were not coincidental; rather, they were inevitable result of the pressurizing human treatments exerted on the environment through the industrial production, irrational consumption patterns...etc.

➢   Algeria has gone through the phase of planned economy, which has resulted huge investment programs that have changed many of the criteria related to poverty, ignorance and illiteracy.

➢   Algeria suffers a lack of strong and powerful industrial policies that support for the SME's. Even the existing policies still have some problems of implementation and inefficiency. Add to that problem, there is also a problem of the bad distribution of industries, as most industries are concentrated in the narrow northern area of Algeria, which is well known for its fertile agrarian lands.

➢   The Algerian authorities started to consider the environmental issues formally since the year 2000. In the last decade, principles of environmental awareness had taken a backseat in the growth considerations during post-independence development euphoria. The government has afforded an increasing attention to environmental protection issues, for instance, by setting up a funding facility in 2001 (L'Agence Nationale pour la Protection de l'Environnement).

➤   The environmental indicators showed that: Algeria ranked 83rd among 180 nations with regard to its environmental policy. According to the EPI 2016 edition, the Peer Comparison Column in the EPI 2016 rankings table identified that it has a better performance than countries in its region. As for the HDI, in 2014 HDR Algeria has been classified as one of the four "Highly Developed" African countries in the human development field.

➤   From the results of the empirical studies, the relationship between economic growth and the pollutant of CO_2 emissions has been investigated based on the EKC hypothesis for Algeria using Ordinary Least Square estimation method, Tanaka (1982) fuzzy regression method and the fuzzy least square regression.

➤   All the estimated models have the correct signs for the estimated models. This suggested an inverted U-shaped relationship between economic growth and environmental degradation. The negative sign of squared term of income seems to corroborate the delinking of CO_2 emissions and real GDP at the higher levels of income.

➤   The Tanaka method is superior to other estimation methods in the sense of reducing the errors.

➤   The reduction of the $CO_{2\ pc}$ emissions as the GDP_{pc} increases was found to be due to the governmental interventions and the lack of economic diversification.

➤   The income turning point was found within the observed sample period. ITP values were ranged in the interval [3500-4500] CO_2 respectively which appeared in 2012.

➤   Algeria passed the ITP for air pollution indicators. In the case of Algeria, passing the income turning point did not prove that this country has necessarily reached to the third industry in its economic development path. Add to that, the economic growth rate is still small compared with the other developing industrial economics like China and India. This reduction in the levels

of CO_2 emissions is due to the slow economic growth in other sectors, except for the hydrocarbon sector and to the legislation intervention of the Algerian government to limit the increase in these pollutants' levels. In this context, Algerian authorities have set out an intervention strategy and initiated a set of actions intended to reduce CO_2 emissions, such as the project of storing CO_2 geologically, which costs 100 million USD, and which was established between the original partners British petroleum (BP) and Sonatrach.

1. Policy Recommendations

The results of this study bear several policy implications for Algeria, and these are addressed as follows:

➢ The finding of income turning points lies within our data range, which shows that the EKC serves as a dangerous guide to environmental policy making in Algeria. Taking the EKC at its face value could send dangerous signals that the economic growth should be the main priority of governments, with the environmental protection set as a secondary priority. Algerian policy makers also need to be aware of the studies on environmental sustainability that strongly suggest that the social welfare should be the primary focus of government policies by increasing the income per capita.

➢ The government should support the raise of less polluting intensive industries in the international market, which will push pollution intensive industries towards a clean production and promote the allocation of new industries in the reasonable regions.

➢ There should be an increase in spreading the environmental awareness inside the Algerian society through advertisements, other media tools and educational programs ...etc.

➢   The key measures to promote the sustainable development is to make a fundamental change in the growth model to protect the ecological environment, and to use green technology to change the traditional way of production to a higher efficient and environmental friendly way.

➢   There should be an increase in the infrastructural development in the southern part of Algeria to help in creating economic projects and new jobs to reduce the high concentration of population in the northern part of the country. The current imbalanced distribution creates many economic and environmental problems such as the decrease in agricultural surface, the increase in air, water and noise pollution and the increases in the prices of real estate.

➢   A foreign direct investment should be encouraged and supported in the agricultural sector and the non-hydrocarbons projects. Foreign direct investment brings a bundle of management experiences such as marketing channels and technology, which provide a unique opportunity to learn from other countries and thereby avoid falling into mistakes.

➢   Strengthening and enforcing environmental regulations is an effective way to prevent the pollution intensive industry transferring to Algeria from other developed countries.

➢   The country should work on the sustainable utilization of resources by constructing an agricultural industry system and encouraging scientific research in the field of sustainable development and clean energy.

➢   Improving the financial system and intensifying reforms help in increasing the number of SME's in Algeria to diversify the economy. That can be through facilitating the funding processes for agriculture industrialization and non-hydrocarbons sector.

➢   According to the requirements of environmental protection, the overall size of the polluted industries in the coastal area should be controlled; otherwise, it will cause damage to the environment.

2. Suggestions for Further Studies

This research opens various new horizons for other future further research about the economic growth and environment in Algeria. Accordingly, several new subjects are proposed, such as:

- The future impact of energy consumptions on air pollution in Algeria.

- The impact of population density in the northern part on the water pollution in Algeria.

- The rule of the environmental awareness in reducing solid waste in cities.

- The rule of the religious awareness in making people more committed to the strict rules of environmental protection.

- The future plans/ methods that guide the Algerian industries towards green economy.

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Appendices

Appendices

1. Countries' Ranks According to Doing Business 2015 Report

Rank	Economy	DTF score		Rank	Economy	DTF score		Rank	Economy	DTF score	
1	Singapore	87.34		64	Jamaica	67.27	↑	127	Cambodia	55.22	↑
2	New Zealand	86.79	↑	65	Bahrain	66.81	↑	128	Maldives	55.04	
3	Denmark	84.40	↑	66	Kosovo	66.22	↑	129	West Bank and Gaza	54.83	↑
4	Korea, Rep.	83.88		67	Kyrgyz Republic	66.01	↑	130	India	54.68	↑
5	Hong Kong SAR, China	83.67	↑	68	Qatar	65.97	↑	131	Egypt, Arab Rep.	54.43	↑
6	United Kingdom	82.46	↑	69	Panama	65.74		132	Tajikistan	54.19	↑
7	United States	82.15		70	Oman	65.40	↑	133	Mozambique	53.98	↑
8	Sweden	81.72	↑	71	Bhutan	65.21	↑	134	Lao PDR	53.77	↑
9	Norway	81.61	↑	72	Botswana	64.98	↑	135	Grenada	53.46	↑
10	Finland	81.05	↑	73	South Africa	64.89		136	Palau	53.43	
11	Taiwan, China	80.55	↑	74	Tunisia	64.88	↑	137	Guyana	51.83	
12	Macedonia, FYR	80.18	↑	75	Morocco	64.51	↑	138	Pakistan	51.69	↑
13	Australia	80.08		76	San Marino	64.21	↑	139	Tanzania	51.62	↑
14	Canada	80.07	↑	77	St. Lucia	64.20	↑	140	Marshall Islands	51.58	
15	Germany	79.87	↑	78	Tonga	64.13		141	Malawi	51.03	↑
16	Estonia	79.49	↑	79	Bosnia and Herzegovina	63.71	↑	142	Côte d'Ivoire	50.93	↑
17	Ireland	79.15	↑	80	Malta	63.70	↑	143	Burkina Faso	50.81	↑
18	Malaysia	79.13	↑	81	Guatemala	63.49	↑	143	Mali	50.81	↑
19	Iceland	78.93	↑	82	Saudi Arabia	63.17	↑	145	Papua New Guinea	50.74	↑
20	Lithuania	78.88	↑	83	Ukraine	63.04	↑	146	Ethiopia	49.73	↑
21	Austria	78.38	↑	84	Brunei Darussalam	62.93	↑	147	Sierra Leone	49.69	↑
22	Latvia	78.06	↑	84	China	62.93	↑	148	Micronesia, Fed. Sts.	49.67	
23	Portugal	77.57	↑	86	El Salvador	62.76	↑	149	Kiribati	49.50	
24	Georgia	77.45	↑	87	Uzbekistan	62.60	↑	150	Togo	49.03	↑
25	Poland	76.45	↑	88	Fiji	62.58	↑	151	Gambia, The	48.99	↑
26	Switzerland	76.04	↑	88	Trinidad and Tobago	62.58		152	Burundi	48.82	↑
27	France	75.96	↑	90	Vietnam	62.10	↑	153	Senegal	48.57	↑
28	Netherlands	75.94		91	Dominica	61.44	↑	154	Comoros	48.22	↑
29	Slovak Republic	75.62	↑	92	Uruguay	61.21	↑	155	Zimbabwe	48.17	↑
29	Slovenia	75.62	↑	93	Dominican Republic	61.16	↑	156	Suriname	47.69	↑
31	United Arab Emirates	75.10	↑	94	Vanuatu	61.08	↑	157	Bolivia	47.47	↑
32	Mauritius	75.05	↑	95	Seychelles	61.05	↑	158	Benin	47.15	↑
33	Spain	74.86	↑	96	Samoa	60.70	↑	159	Sudan	46.97	↑
34	Japan	74.72		97	Albania	60.50		160	Niger	46.37	↑
35	Armenia	74.22	↑	97	Zambia	60.50		161	Iraq	46.06	
36	Czech Republic	73.95	↑	99	Nepal	60.41	↑	162	Gabon	45.99	
37	Romania	73.78	↑	100	Paraguay	60.19		163	Algeria	45.72	↑
38	Bulgaria	73.72	↑	101	Kuwait	60.17	↑	164	Madagascar	45.68	↑
38	Mexico	73.72	↑	101	Namibia	60.17	↑	165	Guinea	45.54	↑
40	Croatia	72.71	↑	103	Philippines	60.07	↑	166	São Tomé and Príncipe	45.50	↑
41	Kazakhstan	72.68	↑	104	Antigua and Barbuda	59.70		167	Myanmar	45.27	↑
42	Hungary	72.57	↑	105	Swaziland	59.10	↑	168	Mauritania	44.74	↑
43	Belgium	72.50	↑	106	Bahamas, The	59.00	↑	169	Nigeria	44.69	↑
44	Belarus	72.33	↑	107	Sri Lanka	58.96	↑	170	Yemen, Rep.	44.54	↑
45	Italy	72.07	↑	108	Kenya	58.24	↑	171	Djibouti	44.25	↑
46	Montenegro	71.85	↑	109	Indonesia	58.12	↑	172	Cameroon	44.11	↑
47	Cyprus	71.78	↑	110	Honduras	58.06	↑	173	Timor-Leste	44.02	
48	Chile	71.49	↑	111	St. Vincent and the Grenadines	57.91	↑	174	Bangladesh	43.10	↑
49	Thailand	71.42	↑	112	Solomon Islands	57.86	↑	175	Syrian Arab Republic	42.56	
50	Peru	71.33		113	Jordan	57.84	↑	176	Congo, Rep.	41.88	↑
51	Russian Federation	70.99	↑	114	Ghana	57.69	↑	177	Afghanistan	40.58	
52	Moldova	70.97	↑	114	Lesotho	57.69	↑	178	Guinea-Bissau	40.56	↑
53	Israel	70.56		116	Brazil	57.67	↑	179	Liberia	40.19	↑
54	Colombia	70.43	↑	117	Ecuador	57.47	↑	180	Equatorial Guinea	40.03	
55	Turkey	69.16		118	Iran, Islamic Rep.	57.44	↑	181	Angola	39.64	↑
56	Mongolia	68.83	↑	119	Barbados	56.85		182	Haiti	39.56	↑
57	Puerto Rico (U.S.)	68.73		120	Belize	56.83	↑	183	Chad	38.22	↑
58	Costa Rica	68.55	↑	121	Argentina	56.78		184	Congo, Dem. Rep.	38.14	↑
59	Serbia	68.41	↑	122	Uganda	56.64	↑	185	Central African Republic	36.26	↑
60	Greece	68.38	↑	123	Lebanon	56.39		186	Venezuela, RB	35.51	
61	Luxembourg	68.31		124	St. Kitts and Nevis	55.83	↑	187	South Sudan	34.78	
62	Rwanda	68.12		125	Nicaragua	55.78	↑	188	Libya	31.77	
63	Azerbaijan	67.80	↑	126	Cabo Verde	55.54	↑	189	Eritrea	27.61	↑

Source: Doing Business database.

Note: The rankings are benchmarked to June 2015 and based on the average of each economy's distance to frontier (DTF) scores for the 10 topics included in this year's aggregate ranking. For the economies for which the data cover two cities, scores are a population-weighted average for the two cities. An arrow indicates an improvement in the score between 2014 and 2015 (and therefore an improvement in the overall business environment as measured by *Doing Business*), while the absence of one indicates either no improvement or a deterioration in the score. The score for both years is based on the new methodology.

2. Tanaka Linear Programming Objective Function and Constraints' Equations

In this study, there are 44+44+3+3 constraints equations, this can be written as:

Var $s_0 >= 0$

Var $s_1 >= 0$

Var $s_2 >= 0$

Var c_0

Var c_1

Var c_2

Minimize $44 * s_0 + 160461.73061 * s_1 + 597173128.93 * s_2$

Constraint $c[1]: c_0 + 2692.633111 * c_1 + 7250273.071 * c_2$
$- s_0 - 2692.633111 * s_1 - 7250273.071 * s_2 <= 1.0360$

Constraint $c[2]: c_0 + 2322.1 * c_1 + 5392148.41 * c_2$
$- s_0 - 2322.1 * s_1 - 5392148.41 * s_2 <= 1.2479$

Constraint $c[3]: c_0 + 2878.6 * c_1 + 8286337.96 * c_2$
$- s_0 - 2878.6 * s_1 - 8286337.96 * s_2 <= 1.8436$

Constraint $c[4]: c_0 + 2907.6 * c_1 + 8454137.76 * c_2$
$- s_0 - 2907.6 * s_1 - 8454137.76 * s_2 <= 2.4242$

Constraint $c[5]: c_0 + 3040.4 * c_1 + 9244032.16 * c_2$
$- s_0 - 3040.4 * s_1 - 9244032.16 * s_2 <= 1.9638$

Constraint $c[6]: c_0 + 3105.5 * c_1 + 9644130.25 * c_2$
$- s_0 - 3105.5 * s_1 - 9644130.25 * s_2 <= 1.917$

Constraint $c[7]: c_0 + 3271.7 * c_1 + 10704020.89 * c_2$
$- s_0 - 3271.7 * s_1 - 10704020.89 * s_2 <= 2.2787$

Constraint $c[8]: c_0 + 3346.4 * c_1 + 11198392.96 * c_2$
$- s_0 - 3346.4 * s_1 - 11198392.96 * s_2 <= 2.3681$

Constraint c[9]: $c_0 + 3550 * c_1 + 12602500 * c_2$
$- s_0 - 3550 * s_1 + 12602500 * s_2 <= 3,4334$

Constraint c[10]: $c_0 + 3703,9 * c_1 + 13718875,21 * c_2$
$- s_0 - 3703,9 * s_1 + 13718875,21 * s_2 <= 2,4317$

Constraint c[11]: $c_0 + 3621,8 * c_1 + 13117435,24 * c_2$
$- s_0 - 3621,8 * s_1 + 13117435,24 * s_2 <= 3,4399$

Constraint c[12]: $c_0 + 3617,1 * c_1 + 13083412,41 * c_2$
$- s_0 - 3617,1 * s_1 + 13083412,41 * s_2 <= 2,3285$

Constraint c[13]: $c_0 + 3730,4 * c_1 + 13915884,16 * c_2$
$- s_0 - 3730,4 * s_1 + 13915884,16 * s_2 <= 1,9086$

Constraint c[14]: $c_0 + 3811 * c_1 + 14523721 * c_2$
$- s_0 - 3811 * s_1 + 14523721 * s_2 <= 2,479$

Constraint c[15]: $c_0 + 3902,1 * c_1 + 15226384,41 * c_2$
$- s_0 - 3902,1 * s_1 + 15226384,41 * s_2 <= 3,2476$

Constraint c[16]: $c_0 + 3925,9 * c_1 + 15412690,81 * c_2$
$- s_0 - 3925,9 * s_1 + 15412690,81 * s_2 <= 3,2255$

Constraint c[17]: $c_0 + 3827,1 * c_1 + 14646694,41 * c_2$
$- s_0 - 3827,1 * s_1 + 14646694,41 * s_2 <= 3,282$

Constraint c[18]: $c_0 + 3692,8 * c_1 + 13636771,84 * c_2$
$- s_0 - 3692,8 * s_1 + 13636771,84 * s_2 <= 3,5171$

Constraint c[19]: $c_0 + 3555,7 * c_1 + 12643002,49 * c_2$
$- s_0 - 3555,7 * s_1 + 12643002,49 * s_2 <= 3,4137$

Constraint c[20]: $c_0 + 3614,3 * c_1 + 13063164,49 * c_2$
$- s_0 - 3614,3 * s_1 + 13063164,49 * s_2 <= 3,1692$

Constraint c[21]: $c_0 + 3551,1 * c_1 + 12610311,21 * c_2$
$- s_0 - 3551,1 * s_1 + 12610311,21 * s_2 <= 3,0079$

Constraint c[22]: $c_0 + 3423,7 * c_1 + 11721721,69 * c_2$
$- s_0 - 3423,7 * s_1 + 11721721,69 * s_2 <= 3,02$

Constraint c[23]: $c_0 + 3405 * c_1 + 11594025 * c_2$
$- s_0 - 3405 * s_1 + 11594025 * s_2 <= 2,976$

Constraint c1[24]: $c_0 + 3260,9 * c_1 + 10633468,81 * c_2$
$- s_0 - 3260,9 * s_1 + 10633468,81 * s_2 <= 2,9617$

Constraint c1[25]: $c_0 + 3165,9 * c_1 + 10022922,81 * c_2$
$- s_0 - 3165,9 * s_1 + 10022922,81 * s_2 <= 3,0499$

Constraint c1[26]: $c_0 + 3224,6 * c_1 + 10398045,16 * c_2$
$- s_0 - 3224,6 * s_1 + 10398045,16 * s_2 <= 3,2987$

Constraint $c[27]: c_0 + 3298{,}8 * c_1 + 10882081{,}44 * c_2$
$$- s_0 - 3298{,}8 * s_1 + 10882081{,}44 * s_2 <= 3{,}3025$$

Constraint $c[28]: c_0 + 3282 * c_1 + 10771524 * c_2$
$$- s_0 - 3282 * s_1 + 10771524 * s_2 <= 2{,}9509$$

Constraint $c[29]: c_0 + 3398{,}3 * c_1 + 11548442{,}89 * c_2$
$$- s_0 - 3398{,}3 * s_1 + 11548442{,}89 * s_2 <= 3{,}5297$$

Constraint $c[30]: c_0 + 3458{,}1 * c_1 + 11958455{,}61 * c_2$
$$- s_0 - 3458{,}1 * s_1 + 11958455{,}61 * s_2 <= 2{,}9941$$

Constraint $c[31]: c_0 + 3541{,}5 * c_1 + 12542222{,}25 * c_2$
$$- s_0 - 3541{,}5 * s_1 + 12542222{,}25 * s_2 <= 2{,}8198$$

Constraint $c[32]: c_0 + 3600{,}8 * c_1 + 12965760{,}64 * c_2$
$$- s_0 - 3600{,}8 * s_1 + 12965760{,}64 * s_2 <= 2{,}6683$$

Constraint $c[33]: c_0 + 3754{,}9 * c_1 + 14099274{,}01 * c_2$
$$- s_0 - 3754{,}9 * s_1 + 14099274{,}01 * s_2 <= 2{,}84$$

Constraint $c[34]: c_0 + 3975 * c_1 + 15800625 * c_2$
$$- s_0 - 3975 * s_1 + 15800625 * s_2 <= 2{,}8564$$

Constraint $c[35]: c_0 + 4092{,}5 * c_1 + 16748556{,}25 * c_2$
$$- s_0 - 4092{,}5 * s_1 + 16748556{,}25 * s_2 <= 2{,}727$$

Constraint $c[36]: c_0 + 4275{,}3 * c_1 + 18278190{,}09 * c_2$
$$- s_0 - 4275{,}3 * s_1 + 18278190{,}09 * s_2 <= 3{,}2202$$

Constraint $c[37]: c_0 + 4285{,}89 * c_1 + 18368938{,}81 * c_2$
$$- s_0 - 4285{,}89 * s_1 + 18368938{,}81 * s_2 <= 2{,}9975$$

Constraint $c[38]: c_0 + 4365{,}3 * c_1 + 19055844{,}09 * c_2$
$$- s_0 - 4365{,}3 * s_1 + 19055844{,}09 * s_2 <= 3{,}1959$$

Constraint $c[39]: c_0 + 4399{,}6 * c_1 + 19356480{,}16 * c_2$
$$- s_0 - 4399{,}6 * s_1 + 19356480{,}16 * s_2 <= 3{,}1685$$

Constraint $c[40]: c_0 + 4395{,}39 * c_1 + 19319541{,}16 * c_2$
$$- s_0 - 4395{,}39 * s_1 + 19319541{,}16 * s_2 <= 3{,}4301$$

Constraint $c[41]: c_0 + 4473{,}5 * c_1 + 20012202{,}25 * c_2$
$$- s_0 - 4473{,}5 * s_1 + 20012202{,}25 * s_2 <= 3{,}3072$$

Constraint $c[42]: c_0 + 4517{,}8 * c_1 + 20410516{,}84 * c_2$
$$- s_0 - 4517{,}8 * s_1 + 20410516{,}84 * s_2 <= 3{,}3006$$

Constraint $c[43]: c_0 + 4581{,}3 * c_1 + 20988309{,}69 * c_2$
$$- s_0 - 4581{,}3 * s_1 + 20988309{,}69 * s_2 <= 3{,}4719$$

Constraint $c[44]: c_0 + 4617{,}5 * c_1 + 21321306{,}25 * c_2$
$$- s_0 - 4617{,}5 * s_1 + 21321306{,}25 * s_2 <= 3{,}5148$$

Constraint c1[1] : $c_0 + 2692.633111 * c_1 + 7250273.071 * c_2$
$- s_0 - 2692.633111 * s_1 - 7250273.071 * s_2 >= 1.0360$

Constraint c1[2] : $c_0 + 2322.1 * c_1 + 5392148.41 * c_2$
$- s_0 - 2322.1 * s_1 - 5392148.41 * s_2 >= 1.2479$

Constraint c1[3] : $c_0 + 2878.6 * c_1 + 8286337.96 * c_2$
$- s_0 - 2878.6 * s_1 - 8286337.96 * s_2 >= 1.8436$

Constraint c1[4] : $c_0 + 2907.6 * c_1 + 8454137.76 * c_2$
$- s_0 - 2907.6 * s_1 - 8454137.76 * s_2 >= 2.4242$

Constraint c1[5] : $c_0 + 3040.4 * c_1 + 9244032.16 * c_2$
$- s_0 - 3040.4 * s_1 - 9244032.16 * s_2 >= 1.9638$

Constraint c1[6] : $c_0 + 3105.5 * c_1 + 9644130.25 * c_2$
$- s_0 - 3105.5 * s_1 - 9644130.25 * s_2 >= 1.917$

Constraint c1[7] : $c_0 + 3271.7 * c_1 + 10704020.89 * c_2$
$- s_0 - 3271.7 * s_1 - 10704020.89 * s_2 >= 2.2787$

Constraint c1[8] : $c_0 + 3346.4 * c_1 + 11198392.96 * c_2$
$- s_0 - 3346.4 * s_1 - 11198392.96 * s_2 >= 2.3681$

Constraint c1[9] : $c_0 + 3550 * c_1 + 12602500 * c_2$
$- s_0 - 3550 * s_1 + 12602500 * s_2 >= 3,4334$

Constraint c1[10] : $c_0 + 3703,9 * c_1 + 13718875,21 * c_2$
$- s_0 - 3703,9 * s_1 + 13718875,21 * s_2 >= 2,4317$

Constraint c1[11] : $c_0 + 3621,8 * c_1 + 13117435,24 * c_2$
$- s_0 - 3621,8 * s_1 + 13117435,24 * s_2 >= 3,4399$

Constraint c1[12] : $c_0 + 3617,1 * c_1 + 13083412,41 * c_2$
$- s_0 - 3617,1 * s_1 + 13083412,41 * s_2 >= 2,3285$

Constraint c1[13] : $c_0 + 3730,4 * c_1 + 13915884,16 * c_2$
$- s_0 - 3730,4 * s_1 + 13915884,16 * s_2 >= 1,9086$

Constraint c1[14] : $c_0 + 3811 * c_1 + 14523721 * c_2$
$- s_0 - 3811 * s_1 + 14523721 * s_2 >= 2,479$

Constraint c1[15] : $c_0 + 3902,1 * c_1 + 15226384,41 * c_2$
$- s_0 - 3902,1 * s_1 + 15226384,41 * s_2 >= 3,2476$

Constraint c1[16] : $c_0 + 3925,9 * c_1 + 15412690,81 * c_2$
$- s_0 - 3925,9 * s_1 + 15412690,81 * s_2 >= 3,2255$

Constraint c1[17] : $c_0 + 3827,1 * c_1 + 14646694,41 * c_2$
$- s_0 - 3827,1 * s_1 + 14646694,41 * s_2 >= 3,282$

Constraint c1[18] : $c_0 + 3692,8 * c_1 + 13636771,84 * c_2$
$- s_0 - 3692,8 * s_1 + 13636771,84 * s_2 >= 3,5171$

Constraint c1[19] : $c_0 + 3555,7 * c_1 + 12643002,49 * c_2$
$- s_0 - 3555,7 * s_1 + 12643002,49 * s_2 >= 3,4137$

Constraint c1[20] : $c_0 + 3614,3 * c_1 + 13063164,49 * c_2$
$- s_0 - 3614,3 * s_1 + 13063164,49 * s_2 >= 3,1692$

Constraint c1[21] : $c_0 + 3551,1 * c_1 + 12610311,21 * c_2$
$- s_0 - 3551,1 * s_1 + 12610311,21 * s_2 >= 3,0079$

Constraint c1[22] : $c_0 + 3423,7 * c_1 + 11721721,69 * c_2$
$- s_0 - 3423,7 * s_1 + 11721721,69 * s_2 >= 3,02$

Constraint c1[23] : $c_0 + 3405 * c_1 + 11594025 * c_2$
$- s_0 - 3405 * s_1 + 11594025 * s_2 >= 2,976$

Constraint c1[24] : $c_0 + 3260,9 * c_1 + 10633468,81 * c_2$
$- s_0 - 3260,9 * s_1 + 10633468,81 * s_2 >= 2,9617$

Constraint c1[25] : $c_0 + 3165,9 * c_1 + 10022922,81 * c_2$
$- s_0 - 3165,9 * s_1 + 10022922,81 * s_2 >= 3,0499$

Constraint c1[26] : $c_0 + 3224,6 * c_1 + 10398045,16 * c_2$
$- s_0 - 3224,6 * s_1 + 10398045,16 * s_2 >= 3,2987$

Constraint c1[27] : $c_0 + 3298,8 * c_1 + 10882081,44 * c_2$
$- s_0 - 3298,8 * s_1 + 10882081,44 * s_2 > = 3,3025$

Constraint c1[28] : $c_0 + 3282 * c_1 + 10771524 * c_2$
$- s_0 - 3282 * s_1 + 10771524 * s_2 > = 2,9509$

Constraint c1[29] : $c_0 + 3398,3 * c_1 + 11548442,89 * c_2$
$- s_0 - 3398,3 * s_1 + 11548442,89 * s_2 > = 3,5297$

Constraint c1[30] : $c_0 + 3458,1 * c_1 + 11958455,61 * c_2$
$- s_0 - 3458,1 * s_1 + 11958455,61 * s_2 > = 2,9941$

Constraint c1[31] : $c_0 + 3541,5 * c_1 + 12542222,25 * c_2$
$- s_0 - 3541,5 * s_1 + 12542222,25 * s_2 > = 2,8198$

Constraint c1[32] : $c_0 + 3600,8 * c_1 + 12965760,64 * c_2$
$- s_0 - 3600,8 * s_1 + 12965760,64 * s_2 > = 2,6683$

Constraint c1[33] : $c_0 + 3754,9 * c_1 + 14099274,01 * c_2$
$- s_0 - 3754,9 * s_1 + 14099274,01 * s_2 > = 2,84$

Constraint c1[34] : $c_0 + 3975 * c_1 + 15800625 * c_2$
$- s_0 - 3975 * s_1 + 15800625 * s_2 > = 2,8564$

Constraint c1[35] : $c_0 + 4092,5 * c_1 + 16748556,25 * c_2$
$- s_0 - 4092,5 * s_1 + 16748556,25 * s_2 > = 2,727$

Constraint c1[36]: $c_0 + 4275,3*c_1 + 18278190,09*c_2$
$- s_0 - 4275,3*s_1 + 18278190,09*s_2 > = 3,2202$

Constraint c1[37]: $c_0 + 4285,89*c_1 + 18368938,81*c_2$
$- s_0 - 4285,89*s_1 + 18368938,81*s_2 > = 2,9975$

Constraint c1[38]: $c_0 + 4365,3*c_1 + 19055844,09*c_2$
$- s_0 - 4365,3*s_1 + 19055844,09*s_2 > = 3,1959$

Constraint c1[39]: $c_0 + 4399,6*c_1 + 19356480,16*c_2$
$- s_0 - 4399,6*s_1 + 19356480,16*s_2 > = 3,1685$

Constraint c1[40]: $c_0 + 4395,39*c_1 + 19319541,16*c_2$
$- s_0 - 4395,39*s_1 + 19319541,16*s_2 > = 3,4301$

Constraint c1[41]: $c_0 + 4473,5*c_1 + 20012202,25*c_2$
$- s_0 - 4473,5*s_1 + 20012202,25*s_2 > = 3,3072$

Constraint c1[42]: $c_0 + 4517,8*c_1 + 20410516,84*c_2$
$- s_0 - 4517,8*s_1 + 20410516,84*s_2 > = 3,3006$

Constraint c1[43]: $c_0 + 4581,3*c_1 + 20988309,69*c_2$
$- s_0 - 4581,3*s_1 + 20988309,69*s_2 > = 3,4719$

Constraint c1[44]: $c_0 + 4617,5*c_1 + 21321306,25*c_2$
$- s_0 - 4617,5*s_1 + 21321306,25*s_2 >= 3,5148$