T. C.
YASAR UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS
MASTER THESIS

MODELING CARBON DIOXIDE AND SULFUR DIOXIDE EMISSIONS USING DYNAMIC PANEL TECHNIQUES: EVIDENCE ON THE ENVIRONMENTAL KUZNETS CURVE (EKC)

Ebru YEŞİLÇAYIR

SUPERVISOR

Assist. Prof. Ayşe Özden BİRKAN

İzmir-2016

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Ayşe Özden Birkan

(Supervisor)

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Alper Duman

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Şaban Çelik

Associate Professor Çağrı Bulut

Director of the Graduate School

YEMİN METNİ

Yüksek Lisans tezi olarak sunduğum **"Modeling Carbon Dioxide and Sulfur Dioxide Emissions Using Dynamic Panel Techniques: Evidence on the Environmental Kuznets Curve (EKC)"** adlı çalışmanın, tarafımdan bilimsel ahlak ve geleneklere aykırı düşecek bir yardıma başvurmaksızın yazıldığını ve yararlandığım eserlerin bibliyografyada gösterilenlerden oluştuğunu, bunlara atıf yapılarak yararlanılmış olduğunu belirtir ve bunu onurumla doğrularım.

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ABSTRACT

Master Thesis

MODELING CARBON DIOXIDE AND SULFUR DIOXIDE EMISSIONS USING DYNAMIC PANEL TECHNIQUES: EVIDENCE ON THE ENVIRONMENTAL KUZNETS CURVE (EKC)

Ebru YEŞİLÇAYIR

Yasar University
Graduate School of Social Sciences
Department of Economics

This thesis investigated the relationship between per capita income and environmental degradation at the global level, using annual data on carbon dioxide (CO_2) and sulfur dioxide (SO_2) emissions. The specific objective was to estimate the environmental Kuznets curve (EKC) for two indicators of environmental quality and to establish whether the estimated relationships conform to the inverted U-shape and N-shape hypothesis. For the empirical investigation, the first econometric model was constructed for carbon dioxide emissions as a proxy for global warming and the second econometric model was constructed for sulfur dioxide emissions as a proxy for air pollution. Income, the square of income, the cube of income, energy efficiency, industry, coal and alternative (non-fossil) sources of electricity production as well as two different indexes of democracy were used as regressors in both models. In this thesis, the first econometric model was estimated for 119 nations from 1990 to 2011, while the second econometric model was estimated for 118 nations from 1990 to 2005. Both econometric models used the system Generalized Method of Moments (GMM) estimator in order to grasp cumulative environmental quality changes. Fixed/random effects estimators which are commonly preferred in previous panel estimations of static environmental Kuznets curve equations were also reported. The empirical results showed that the environmental Kuznets curve relationship differed depending on the type of the pollutants. More specifically, global pollutants exhibited the U-shaped and the inverted N-shaped environmental Kuznets curve, whereas local pollutants generally followed the "conventional" environmental Kuznets curve. Thus, it was concluded that environmental policy should consider the different characteristics of global and local pollutants.

Key Words: Air Pollution, Global Warming, Global Pollutants, Local Pollutants, Environmental Kuznets Curve

ÖZET

Yüksek Lisans

KARBONDİOKSİT VE SÜLFÜR DİOKSİT EMİSYONLARININ DİNAMİK PANEL TEKNİKLERİ KULLANILARAK MODELLENMESİ: ÇEVRESEL KUZNETS EĞRİSİ (ÇKE) ÖRNEĞİ

Ebru YEŞİLÇAYIR

Yaşar Üniversitesi

Sosyal Bilimler Enstitüsü

Ekonomi Yüksek Lisans Programı

Bu tez küresel düzeyde kişi başına düşen gelir ve çevresel bozulma arasındaki ilişkiyi yıllık karbondioksit (CO_2) ve sülfür dioksit (SO_2) emisyon verilerini kullanarak araştırmıştır. Temel amaç çevresel Kuznets eğrisini (ÇKE) iki farklı çevresel kalite indikatörü için tahmin etmek ve tahmin edilen ilişkinin ters U ve N hipotezleriyle uyumlu olup olmadığını ortaya koymaktır. Bu ampirik araştırma kapsamında, birinci ekonometrik model küresel ısınma için temsili olan karbondioksit emisyonlarını ve ikinci ekonometrik model hava kirliliği için temsili olan sülfür dioksit emisyonlarını bağımlı değişken, gelir, gelirin karesi, gelirin küpü, enerji verimliliği, endüstri, kömür ve alternatif (fosil olmayan) kaynaklardan yapılan elektrik üretimi ve iki farklı demokrasi endeksini regresör olarak ele almaktadır. Bu tezde, birinci ekonometrik model 119 ülke için 1990-2011, ikinci ekonometrik model ise 118 ülke için 1990-2005 dönemi için tahmin edilmiştir. İki ekonometrik model çoğunlukla geçmiş statik çevresel Kuznets eğrisi panel tahmin denklemlerinde tercih edilen sabit/rassal etkiler tahmincisinin yanısıra birikmiş çevresel kalite değişikliklerini yakalamak amacıyla sistem genelleştirilmiş momentler yöntemi (GMY) tahmincisini de kullanmıştır. Bu ampirik sonuçlara göre, çevresel Kuznets eğrisi kirleticilerin tipine göre değişmektedir. Daha belirgin olarak, küresel kirleticiler U ve ters N çevresel Kuznets eğrisini sergilemektedirler. Diğer yandan yerel kirleticiler genellikle "konvensiyonel" çevresel Kuznets eğrisini izlemektedir. Dolayısıyla, çevresel politikanın farklı karakteristikteki küresel ve yerel emisyonları göz önünde bulundurması gerektiği sonucuna varılmıştır.

Anahtar Sözcükler: Hava Kirliliği, Küresel Isınma, Küresel Kirleticiler, Yerel Kirleticiler, Çevresel Kuznets Eğrisi

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ABBREVIATIONS

A.D.	Anno Domini
ADF	Augmented Dickey Fuller
ALTERNATIVE_ENERGY	Alternative and Nuclear Energy
CH_4	Methane
CIESIN	Center for International Earth Science Information Network
CL	Civil Liberties
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2PC	Carbon Dioxide Emission Per Capita
COAL_ENERGY	Electricity Production from Coal Sources
ECM	Error Correction Model
EDI	Index of Environmental Degradation
EF	Ecological Footprint
EI	Energy Intensity
EKC	Environmental Kuznets Curve
EOP	End of Pipe
EP	Environmental Pressure
EPI	Environmental Performance Index
ESI	Environmental Sustainability Index
EU	European Union
FDI	Foreign Direct Investment
FE	Fixed Effects
FEM	Fixed Effects Model
F-GASES	Gases that contain Fluorine
FH	Freedom House
FIG	Figure
FREEDOM	Sum of the Freedom House Political Rights and Civil Liberties Indices
GDP	Gross Domestic Product
GDPPC	Gross Domestic Product Per Capita
GHGs	Greenhouse Gas Emissions

GMM	Generalized Method of Moments
GMM-DIF	Difference Generalized Method of Moments
GMM-SYS	System Generalized Method of Moments
GNP	Gross National Product
GPT	General Purpose Technologies
H	Hypothesis
INDUS	Industry Value Added
IoU	Intensity of Use Hypothesis
IPCC	International Panel on Climate Change
IPS	Im, Pesaran and Shin
IU	Intensity Use
KC	Kuznets Curve
LCO$_2$PC	Log of CO$_2$ Emissions in Metric Tons Per Capita
LENERGY_EFFICIENCY	Log of GDP Per Unit of Energy Use
LGDPPCPPP	Log of Real GDP Per Capita
LGDPPC^{2}PPP^2	Squared Log of Real GDP Per Capita
LGDPPC^{3}PPP^3	Cubic Log of Real GDP Per Capita
LSO$_2$PC	Log of SO$_2$ Emissions in Metric Tons Per Capita
LtG	Limits to Growth
MI	Material Intensity
MJ	Mega joules
MNCs	Multinational Companies
NASA	National Aeronautics and Space Administration
NO$_x$	Nitrogen Oxides
NO$_2$	Nitrogen Dioxide
O$_3$	Ozone
OECD	Organisation of Economic Co-operation and Development
OLS	Ordinary Least Squares
P	Page No
Pb	Lead
PCA	Principal Component Analysis
PHH	Pollution Haven Hypothesis
PM$_{2.5}$, PM$_{10}$	Particulate Matter
PNNL	Pacific Northwest National Laboratory

POLITY2	The Difference between the Sub-Indexes for Democracy and Autocracy
PP	Phillips Perron
PPM	Parts Per Million
PPP	Purchasing Power Parity
PR	Political Rights
R&D	Research and Development
RE	Random effects
REM	Random Effects Model
SACU	Southern Africa Customs Union
SD	Sustainable Development
SEDAC	Socioeconomic Data and Applications Center
SMEs	Small and Medium-Scale Enterprises
SO_x	Sulfur Oxides
SO_2	Sulfur Dioxide
SO_2PC	Sulfur Dioxide Emission Per Capita
SOLAR PV	Solar Photovoltaic System
SPM	Suspended Particulate Matter
TP	Turning Point
UK	United Kingdom
UN	United Nations
US	United States
WDI	World Development Indicator
W. GERMANY	Western Germany
WTP	Willingness to Pay

CONTENTS

RECORD OF THIS THESIS DEFECE

INTRODUCTION

Global warming and air pollution are intrinsically linked and represent two of the greatest environmental issues of our time. CO_2 is the main cause of global warming, which will sooner than later aggravate food shortages through increased unpredictability of precipitation, hunger and the alteration of water resources, and damage the infrastructure in certain nations due to rising sea-levels and shifting weather patterns (Buehn & Farzanegan, 2013: 104; Nema et al., 2012: 2330). SO_2 is the main cause of air pollution, which severely affects human health, causes acid rain damaging forests, lakes, buildings, cultural objects, and agricultural production, and reduces visibility from light mist to dense gray smog (Bernauer, 2009: 1358). Thus, policy-planning and decision-making processes need to account more than ever for environmental pollution related aspects due to their direct influence on life quality and the economy. This requires a heavy burden for most governments' budgets, accounting for the economic price of poor-quality air (Buehn & Farzanegan, 2013: 104).

Therefore, these issues have received growing attention and considered as one of the most attractive empirical topics of immense interest among economists and policymakers. To curb emissions, define environmentally friendly economic growth plans and design proper policies, identifying the link between development, and global warming as well as air pollution has been great significance. For instance, whether empirical findings show a monotonously positive relationship among them, it represents that air quality will continue to degrade with economic development. Only when economic growth enters a stage of stagnation, the tendency toward poor-quality air would slow. In contrast, if a non-monotonous and nonlinear curve link is found among them, poor-quality air might be reversible and air quality recoverable (Wang et al., 2016: 1182-1183).

From a theoretical point of view, existence of such a non-monotonous and nonlinear curve (analogous to an inverted U-shape curve) link between income per capita and global warming indicators, namely carbon dioxide (CO_2) and air quality indicators, namely sulfur dioxide (SO_2) has been termed as the "environmental Kuznets curve" (EKC) hypothesis. This hypothesis argues that in the early stages of socioeconomic development, environmental quality degrades with the rise of gas emissions, however as the economy continues growing beyond a certain threshold (the turning point), that emissions tends to fall and environmental quality improves, forming an approximately inverted U-shape curve.

Validity of the EKC hypothesis in many previous studies implies that the development vs. environmental protection can be resolved (Wang et al., 2016: 1183). The policy implication of EKCs is that promoting economic growth are "sufficient criteria" to protect the environment. In the long run, the surest way to improve the environment is to become wealth (Dinda, 2004: 445). However, there is by no means a unanimous consensus in the existing literature. In fact, a considerable amount of separate conclusions has been reached in EKC studies, resulting from different data samples, different estimation methods as well as across different pollution indicators (Li et al., 2016: 139).

There are several points that complicate a clear policy conclusion derived from these studies: Firstly, EKC may be not valid for all types of environmental degradation. All pollutants do not obey this empirical regularity, i.e., the EKC relationships are more likely to hold for pollutants with more short-term and local effects rather than those with more global, indirect and long-term effects. Secondly, EKC may be not valid both for individual nations and the World. Developed nations are often associated with lower emission reductions, while developing nations have not yet reached income levels high enough to be able to derive their turning points (Dinda, 2004: 446). Thirdly, many of the EKC studies are based on a cross-section nation basis rather than on a more careful panel or time-series framework within specific nations (Esteve & Tamarit, 2012a: 2697).

This thesis contributes to the literature on EKC studies in three ways. First, it uses CO_2 emissions as the main indicator for global warming and SO_2 emissions as the main indicator for air pollution for a large sample of countries in a panel framework. The reason that it is adopted these different type of emissions in this thesis is twofold. The former, they are the most frequently mentioned indicators for global warming and air pollution in both media and policy debates. Both CO_2 and SO_2 emissions play a focal role in the current debate on environmental protection and sustainable development. CO_2 emissions are a by-product of energy, which is an essential factor in the world economy, while SO_2 emissions are a by-product of goods production. Thus, it aims to compare the empirical results of air pollutants with more direct, short-term and local effects and greenhouse gases with more indirect, long-term and global effects. The latter, as various EKC scenarios (i.e. the different slope and form of the EKC) are found with respect to different substances, policies should be designed and implemented based on the analysis of characteristics of each individual emission. In other words, environmental and energy policies need to be 'customized' for each substance, as a mixed output of various national factors is characterized by uncertainty and abruptness, rather to be standardized (Park & Lee, 2011: 5847).

Second, this thesis tests the EKC hypothesis using a system GMM (GMM-SYS) estimator in order to fill the gap in the existing literature unexploring the study of dynamic EKC specification with lagged dependent variable, along with a fixed effects and random effects model which are traditional techniques commonly used in previous panel estimations of static EKC equations. In fact, there are two main defects in using the static model for estimation. The first defect is that estimations based on these models may suffer from a potential endogeneity problem, since certain variables that affect CO_2 and SO_2 emissions may be omitted from the models (due to data deficiency, there are usually certain variables that cannot be introduced into a regression equation), and the possible bilateral causality between dependent and explanatory variables may also cause endogeneity. The endogeneity could lead to biased estimates of coefficients (Hao et al. 2015: 947).

The second defect is that such models have strong dynamic characteristics, since the dependent variables, CO_2 and SO_2 emissions, are related not only emissions calculated at year *t* but also year *t*-1. Thus, the estimation results may be more reasonable if these dynamic characteristics are fully considered. In this regard, the system GMM (GMM-SYS) estimator is valuable for analyzing the complexity of EKC relationship because environmental quality evolves cumulatively over time. That is, the environmental quality of today is likely to be linked to that of yesterday, rendering it appropriate to regard a dynamic EKC specification that includes lagged dependent variable on the right hand side. All in all, GMM-SYS is the suitable approach in estimating a dynamic EKC specification as it can address the issues of endogeneity, heteroskedasticity, and autocorrelation within the involved variables, since the traditional fixed/random effects estimators would be inefficient and bias when applied to dynamic panel models (Li et al., 2016: 139-140).

Third, besides the income related variable, which turned out to be the most influential variable, other non-income factors, particularly governance factors are tested as independent variables in order to mitigate the omitted variables biases in the earlier EKC studies. Hence, it is expected to be a direct measure of the quality of the environmental protection function of the government (El Anshasy & Katsaiti, 2014: 87). Since democracy indexes mirror various governance aspects and may arguably affect emissions in different ways, thus this thesis employs two different indexes that it find available. Thus, this multivariate framework helps us to understand both how these non-income factors contribute to environmental degradation individually and whether the EKC still survives after controlling for these relevant variables.

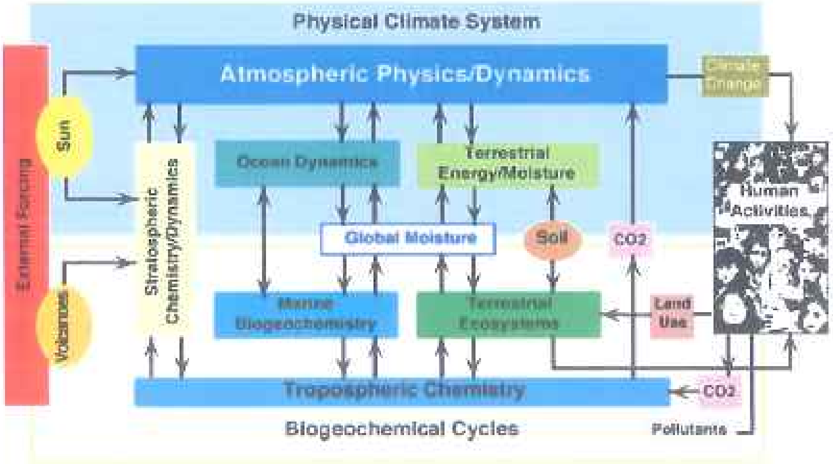
This thesis is organized as follows. Section 1 briefly describes the factors behind the environmental Kuznets curve with empirical evidence from the literature and conceptual and methodological criticisms. Section 2 discusses the literature on environmental quality indicators and presents theoretical considerations for the selection of causes and indicators. Section 3 explains models, estimation methods and data sources used to test the EKC hypothesis. Section 4 presents the empirical results and related discussions. The final section contains concluding comments.

CHAPTER 1

ENVIRONMENTAL KUZNETS CURVE (EKC)

1.1. Global Environmental Degradation and Factors behind the Environmental Kuznets Curve (EKC)

Environmental degradation refers to a process through which the natural environment is compromised in some way, reducing biological diversity and the general health of the environment. This process can be entirely natural in origin, or it can be accelerated by human activities (Hassan et al., 2015: 58). Peter Vitousek (1994), a leading natural scientist, emphasized the importance and magnitude of the second factor. He argued that humans did and always will "alter the structure and function of Earth as a system" (p. 1862). Dramatic examples abound, we are the primary forces responsible for the observed warming of the Earth's atmosphere and the associated ecological consequences of climate change as well as air pollution, particularly over the last 50 years, we have transformed, degraded, and overexploited the world's natural landscapes; and no area of the world's ocean is unaffected by our influence, undermining the services and biodiversity of its ecosystems (see Fig. 1) (Jorgenson & Clark, 2011: 226).



(from Earth System Science: An Overview, NASA, 1988)

Fig. 1. The "Bretherton Diagram" [Source: Palsson et al., 2013, p. 5].

Environmental degradation has been not a recent issue, it has been happening all over the world for centuries. It first began in 1285 A. D. when the city of London experienced air pollution problems from the burning of soft coal (Fisher & Peterson, 1976: 3), and accompanied by the beginning of the "Anthropocene" at around 1780 A. D., represents the beginning of immense rises in human population and carbon emissions and atmospheric CO_2 levels, the so-called 'great acceleration' (Foley et al., 2013: 83). In addition, the current problems of environment have multiplied and changed their character during the past decades; from local to global, from distinct to diffuse, from short time delay between cause and effect to long time delay and from relatively low complexity to high complexity (Robért et al., 1997: 79). James Hansen (2008), a leading U.S. climatologist, argued that the 'planet is dangerously near a tipping point' given the accumulation of carbon dioxide in the atmosphere. As long as we continue with "business-as-usual", in terms of a growing economy predicated on a carbon-based energy system, we may not find enough time for the environment to recover and regenerate itself (Jorgenson & Clark, 2009: 621).

The inescapable scientific conclusion is that we have been living on a "dynamic planet" which presents many challenges, particularly in an era of global warming when we are taxing the limits of ecosystem use in many parts of the world. Given that it is anthropogenic activity that is almost surely the main cause of environmental degradation, it is clear that we can no longer be considered separate from the natural systems we inhabit. All in all, the 21st century has been defined as a "period in man's occupation of this planet". There are two possible cases: Either we continue with the present growth scenarios predicated on a carbon-based energy system which have been central to human economic activity over the past 200 years, and thus put future generations at severe risk from major environmental catastrophes, some of which might be on a global scale, or we scale back our activities to achieve a better balance with our life-support system, the biosphere. There can be no doubt about the magnitude of the challenge of achieving sustainability, a way to live in harmony with the environment, however it is a challenge that must be happened if mankind wishes to occupy a dominant role on this planet for the centuries and even millennia ahead (Glasby, 2002: 342-343).

Worldwide degradation of environmental quality has made many feel concerned about the issue and mounting public concern over environmental issues has stimulated efforts to investigate and understand more clearly the determinants of environmental degradation. Particularly, the linkage of environment with economic growth/development has been receiving increasing attention (Dinda et al., 2000: 409-410). Even though the speed and scale of the transformation of ecosystems is unprecedented, the disparities in environmental degradation are uneven among nations. For instance, wealth nations put more pressure on the global environment, while poorer nations disproportionately challenge with the effects and consequences of degraded ecosystems (Jorgenson & Clark, 2009: 621). In order to respond these questions, the environmental Kuznets curve (EKC) is developed as a theoretical syllogism in order to explain why nations differ from each other in the environmental degradation they challenge and why nations might change over time in generating environmental degradation (Dietz et al., 2012: 21).

The basic logic of the EKC builds on analyses made by Simon Kuznets (1955) regarding economic growth and income disparity. He hypothesized that as an economy grows from low income or gross domestic product per capita (GDPPC) to higher incomes or GDPPC, income disparity first increases, then reaches a turning point and declines thereafter (Dietz et al., 2012: 21). His hypothesis encouraged many economists to assume that fast economic growth might generate, somewhat automatically, a more equal income distribution (Kaika & Zervas, 2013b: 1409). One implication is that a nation can 'grow its way out' of disparity. In the mid-1990s, several economists (Shafik and Bandyopadhyay, 1992; Shafik, 1994; Selden and Song, 1994; Grossman and Krueger, 1995; Stern, Common and Barbier, 1996) suggested that the same logic as for the KC applies to environmental problems: as national economies grow the environmental degradation they challenge increases at first but eventually reaches a "turning point" (TP) where from that point on further growth reduces environmental degradation. Similar implication is that a nation can 'grow its way out' of environmental degradation (Dietz et al., 2012: 21): the growth process itself will solve any environmental problems generated in the earlier stages of development.

These studies have laid the groundwork for intensive literature on the EKC-concept both on theoretical and empirical basis. The main task for the subsequent researchers is to find other than income possible driving forces that might cause an EKC-pattern. This allows us to deepen our understanding of the EKC-concept, how environmental quality will evolve over time. There are several factors that explain this pattern, such as, the equity of income distribution, the fear linked to the limits of growth, intensity of use (IoU) hypothesis, the concept of sustainable development (SD), international trade, foreign direct investment (FDI), the structural changes, technical progress, improvements in energy efficiency, and consumers' preferences, the institutional framework and governance. The significance of these factors might explain sufficiently or partially a possible EKC-pattern (see Fig. 2) (Bo, 2011: 1324; Dinda, 2004: 433; Kaika & Zervas, 2013a: 1394-1400).

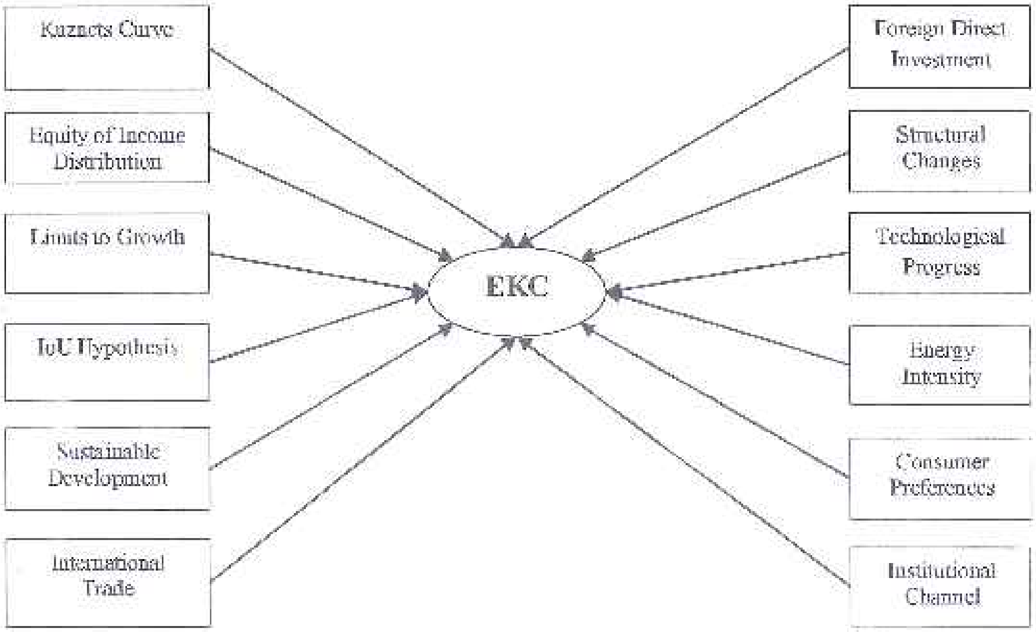


Fig. 2. The Factors behind the Environmental Kuznets Curve (EKC) [Source: Own elaboration based on Bo (2011), Dinda (2004) and Kaika & Zervas (2013a, 2013b)].

The original Kuznets curve focuses on issues related to the effect of economic growth on the distribution of income (Kaika & Zervas, 2013a: 1394). Kuznets (1955, 1963) hypothesized that economic development is fundamentally a sequential and uneven process. In other words, instead of each citizen benefiting at the same time, the process appears to pull up certain groups first and leave the other groups to catch up later. In the initial phase, disparity (inequality) widens. Later, as each citizen catches up, disparity falls. His syllogism implied that economic progress, measured by per capita income, is initially accompanied by increasing disparity, but that these disparities ultimately go away as the benefits of development permeate more widely. In more formal terms, if we plot per capita income on the horizontal axis of an XY chart and some measure of income disparity on the vertical axis, he suggests a plot that looks like an upside-down 'U': therefore the name "Kuznets curve" (KC) or "inverted-U hypothesis" (Ray, 1998: 199-200). (See Fig. 3)

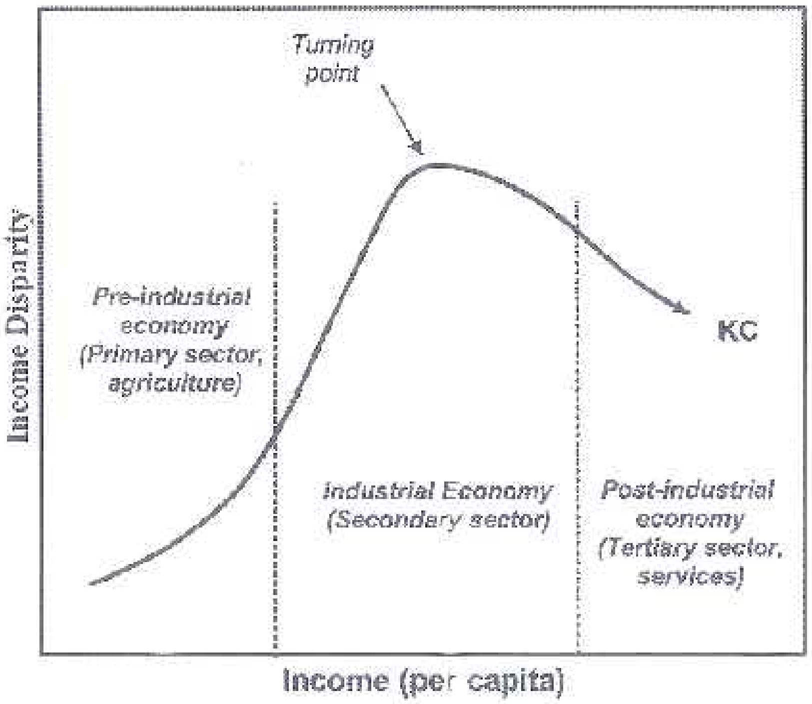


Fig. 3. The Kuznets Curve (KC): Income-Disparity Relationship [Source: Own elaboration based on Kaika & Zervas (2013a)].

The basic logic of the inverted-U Kuznets curve is rather intuitive: in the early stages of industrialization, a nation's economy has the labor force primarily engaged in agriculture. However, as industrialization locates, workers move from the larger agricultural sector to the smaller industrial one and, since wages are usually higher in the industrial sector, this migration enhances further income disparity. As a result of this process, income distribution becomes more unequal as income grows. In addition, as the agricultural sector shrinks and the industry grows in size, further transfers from agriculture to manufacturing decrease rather than increase income disparity. In the same way, this logic can be applied when the economy shifts away from industry towards services. It implies that how income disparity evolves depends on the period of time under investigation (Mollick, 2012: 133-134). Fig. 4 illustrates scale, composition and technique effect on KC.

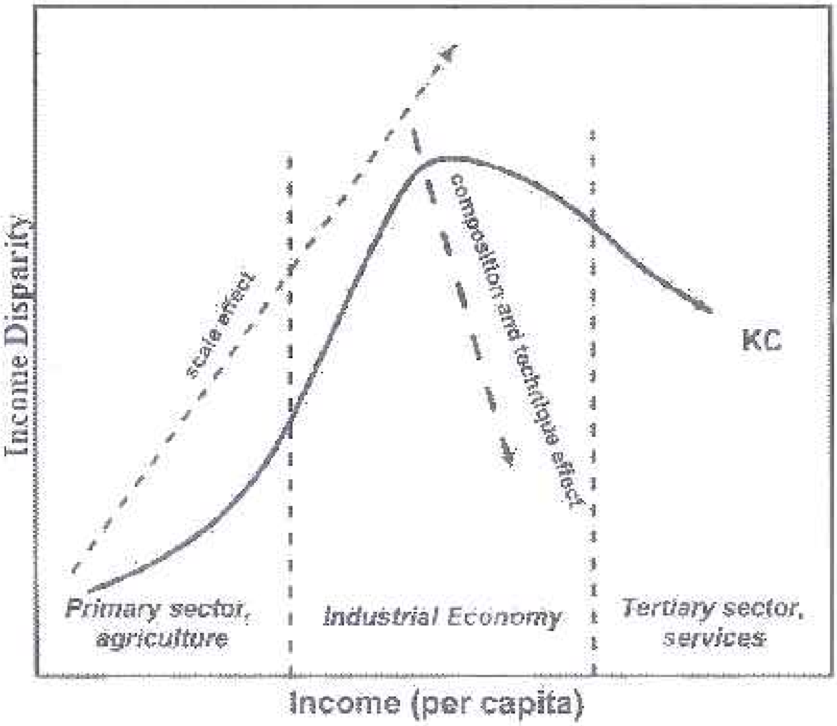


Fig. 4. Scale, Composition and Technique effect on KC [Source: Own elaboration based on Kaika & Zervas (2013a)].

In the years since Kuznets hypothesized, more data have been collected, and his hypothesis has become a touchstone for research in this area as economists have attempted to prove, disprove, or explain the factors behind the Kuznets curve (Weil, 2009: 375). For instance, Ahluwalia (1976) utilized a multiple regression to estimate the cross-country relationships for disparity, and found some support for Kuznets' original assumption that changes in the structure of production provide a mechanism through which development affects disparity. Barro (2000) as well as Randolph and Lott (1993) estimated the relationship between the Gini coefficient and the log of per capita GDP and supported the shape of the Kuznets curve under some conditions (Kijima et al., 2010: 1188-1189).

The economic history, however, has experienced with a substantial income disparity despite rapid income growth. Only few decades after the original Kuznets study in 1955, it is recognized that rapid economic growth process decreased income disparity in some nations, and thus some policy-makers have interpreted such results as conveying an important message about priorities: "Grow first, distribute later". Should a policy of rapid economic growth is adopted; there is every likelihood that there will be substantial income disparity in the end. Kuznets (1955) suggested that researchers studying on income disparity should take into account both the historical and the sociopolitical conditions of each nation; since each nation (or economy) has its own particularities or unique characteristics that should be counted for and not bypassed (Kaika & Zervas, 2013b: 1409).

Many researchers argued that an EKC-pattern appears as a result of the "equity of income distribution". The view is that the process of economic growth generates a more equitable income distribution that improves the relative position of the median agent (citizen) (Kaika & Zervas, 2013a: 1394-1395). A more equitable income distribution might affect a society's environmental quality demand through other routes. That is, a change in income distribution might bring in a new pattern of consumer demand, social harmony and public opinion in favor of environmental quality improvement. Wider literacy, greater political liberty and civil liberties might facilitate a more equitable distribution of income and power, and thus generating environmental improvement (Coondoo & Dinda, 2008: 375-376).

Some scholars began to develop theoretical models to reveal the role of an imbalanced income distribution on the environment (Zhang & Zhao, 2014: 383). The pioneering study was published by Boyce (1994) who argued that the inequality of power and income might be a relevant determinant of environmental degradation, which was examined empirically by Torras and Boyce (1998) (Heerink et al., 2001: 360). They argued that pollution was mitigated or generated depending on the gap of power between agents who bear the burden of pollution against other agents who benefit from pollution although the power of each part is a function of income distribution. More specifically, if income disparity worsens as income increases, the environment will keep degrading, and the opposite way, since agents who suffer from pollution will not be in economic position to impose environmental regulations on other agents who benefit from pollution. Thus, the demand for environmental protection is determined by the improved participation of the agents who bear the burden of pollution that results from a more equitable income distribution, better information access as well as education (Kaika & Zervas, 2013a: 1395).

Many researchers showed a significant effect of income equality on pollution mitigation in certain nations or regions (Kaika & Zervas, 2013a: 1395). Magnani (2000) found that income inequality generates a gap between the nation's ability to pay for environmental protection and a nation's willingness to pay, using OECD data on public R&D expenditure for environmental protection. She concluded that the downward sloping segment of the EKC appears in high-income nations if and only if economic growth does not lead to a 'large' increase in income inequality. Using a sample of nations being at the last stage of economic development, Bimonte (2002) investigated causal linkages between inequality, literacy, information accessibility, and environmental quality. He found that the participation of the agents in the growth process depends on income inequality, information access and education, and acts as a shifter translating the EKC curve upward or downward. This result accounts for why some nations that are at the same level of development have different levels of environmental degradation. Also, Coondoo and Dinda (2008) indicated that inter-country income inequality has a significant effect on the mean emission level and inter-country inequality of emission level for most of the country-groups considered. Moreover, Cantore and Padillia (2010) found that the differences in GDP per capita between rich and poor regions are significant causes of emission distribution among nations.

Others argued that the effect of income inequality on environmental quality is ambiguous. Scruggs (1998) questioned the claims of Boyce (1994), and drew the conclusion that income distribution has nothing to do with environmental policy and the relation between income inequality and environmental quality should be reversed when the income per capita attains a threshold level. The results reinforced the view that assumptions about the structure of preferences and workings of social choice institutions ignore complex interactions which influence the relationship between equality and environmental degradation. In addition, Ravallion et al. (2000) found a reciprocal relationship between income inequality and environmental quality and the relationship would be weakened over the long-term. Moreover, Heerink et al. (2001) concluded that the imbalance in income distribution improves the environmental quality (Zhang & Zhao, 2014: 383).

Many researchers pointed out that an EKC-pattern appears as a result of the transition from issues concerning the depletion of natural resources into current issues concerning either the sustainability of economic growth or the necessity of economic growth to curb environmental degradation (Kaika & Zervas, 2013a: 1393). Before 1970, there was a view that the consumption of raw materials, energy and natural resources grow almost at the same rate as economy grows (Dinda, 2004: 433). However, in 1972, the report of the Club of Rome "the Limits to growth" (LtG) estimated that economic growth has significant environmental implications and the future world would collapse because world economy would reach its physical limits in terms of nonrenewable resources, agricultural production, and excessive pollution. In addition, some vital minerals (copper, gold, lead, mercury, natural gas, oil, silver, tin, and zinc) could be exhausted before the end of this century (Tahvonen, 2000: 4).

A year after the publication of this report, oil prices rose about threefold over a very short time, and therefore the first oil crisis took place. This case raised a general sense that the world was entering a future of increasing scarcity of energy and natural resources. This concern has prompted efforts to investigate whether an economy can maintain a positive consumption level forever, given that there is no technical development and that the production of commodities is possible only by using limited nonrenewable resources. As a result, the concept of "sustainability" and two conflicting theories have been laid the foundation. On one hand, economists argued that it is possible to maintain a positive consumption level forever only if capital can be substituted for nonrenewable resources without technical difficulties. In their view, if the substitution possibilities are limited, future consumption per capita must finally fall to zero. On the other hand, environmental economists argued that substitution possibilities are constrained by physical laws even if technological change is continuous (Tahvonen, 2000: 4-6).

Some years later, the critics argued that the LtG model has several defects in terms of both theoretical and empirical grounds. The first, there was not a given ratio between economic growth and pollution; market adjustments to supply and demand would eventually lead to price changes and to necessary discovery of new resources, development of substitutes and to technological changes. The second, the problem was not the economic growth, but a lack of internalization of the external effects in the price system. In general, the poorest nations tend to have the largest pollution problems, and the least resources to improve the environment (Bruvoll & Medin, 2003: 28). The third, empirical studies showed that the ratio of consumption of some metals to income was declining and following an inverted U-shape in developed economies during the 1970s, which violated the basic tenets of LtG. This inverted U-shape reflected that the intensity of materials-use slowed down beyond a threshold level of income (Dinda, 2004: 433).

One potential explanation for this phenomenon was given by the "Intensity-of-Use" (IoU) hypothesis, first coined by the International Iron and Steel Association (now World Steel Association), and then disseminated in Malenbaum (1973, 1978) (Wårell, 2014: 134). Consistent with the EKC, the basic logic of the IoU revolves around consumption of materials over different stages of economic development. In the infant stage, an economy is largely based on unmechanized agricultural sector with low material or metal use. In the next stage, the economy is industrialized and the consumption of materials rises as the demand for basic infrastructure (roads, railways, buildings, bridges, factories, cities, pipelines, automobiles, power grids) rises. As development advances, the economy is gradually transformed into a service sector-based one. As the taste of consumer changes, they demand more service-based products, and therefore fewer materials are used. Consequently, this trend reverses the positive link between material intensity (MI) and per capita GDP. In conclusion, the theory indicates a unidirectional causality running from per capita GDP to MI while an inverted U-shaped relationship exists between the two variables (Cleveland & Ruth, 1998: 25; Jaunky, 2012: 296-297).

Many researchers found support for the IoU hypothesis for different metals and different nations. Among them, Malenbaum (1977) was the first researcher who studied the IoU. He constructed an MI index in terms of weight consumed per unit in tons per real GDP in constant 1971 US dollars. Concerning the metal intensity trend for 10 world regions and for 12 metals and minerals ores over the period 1950-1975, he concluded to the existence of a bell-shaped trend (Jaunky, 2012: 297). The results reflected that 'man's skill, knowledge, and aspirations' have effectively decoupled economic growth from growth in raw materials use. Larson and colleagues (1986) as well as Williams and colleagues (1987) built on this early study in their analysis of materials use in the United States that concluded in their proposal that the 'era of materials' was over. Larson and colleagues calculated the intensity use (IU) (weight per dollar GNP) for three 'traditional' materials (steel, cement, paper) and four 'modern' materials (aluminum, chlorine, ammonia, ethylene). Their visual inspection of the IU data as a function of per capita GNP exhibited the inverse U shape, with the IU of even the 'modern' materials decreasing as a function of income (Cleveland & Ruth, 1998: 25). Concerning the link between MI and per capita GDP for 30 least developed nations over the period 1977-1987, Lahoni and Tilton (1993) confirmed the IoU hypothesis (Jaunky, 2012: 297).

Some researchers argued that the empirical research shows not only the existence of an EKC for individual nations, but also that differences in the IU of an individual material among nations are explained by differences in their stage of economic development. Bernardini and Galli (1993) suggested that nations complete development in successive periods at about the same level of per capita GDP and that the IU of a given material falls the later in time each nation completes development (Cleveland & Ruth, 1998: 25). Using steel consumption and GDP data for 61 nations over 42 years, Wårell (2014) showed that the IoU hypothesis held for the middle income groups, implying that the nations in this income group experienced the move from an industrialization phase towards a more service based economy in the time period examined. Guzmán et al. (2005) showed that rising per capita income raised the intensity of copper use in Japan over the entire period examined, but further advances would tend to reduce the intensity of copper use due to new-copper saving technologies and other time related variables.

Others researchers argued that it is difficult to interpret the empirical findings of the studies investigating IoU hypothesis. Using a database on total materials use in the US, Rogich (1993) employed regression analysis to compare the IU of paper, wood, metals, and plastics measured in weight and volume terms to per capita GNP from 1970 to 1989. The regression line fitted to the weight-based IU data had a negative slope, but at the same time that fitted to the volume-based IU had a positive slope. Nevertheless, no information was given to show whether the results satisfy any standard criteria for statistical significance. Since, the low R-squared statistics were not 'satisfactory'. If these results were significant, they would confirm that the US was shifting its preferences to lower density materials but that the consumption of materials was not decreasing as the standard of living improved (Cleveland & Ruth, 1998: 26).

In order to measure the effect that structural economic change has had on the environment since the 1970s, Jänicke and colleagues (1989) developed an 'index of structural environmental impacts'. They used four indicators 'whose direct and/or indirect environmental significance is indisputable', i.e., the consumption (weight) of steel, energy, cement, and the weight of freight transport by road and rail, proxy for 'volume aspect of production'. They calculated per capita consumption of each indicator, and then calculated the deviation from the mean for each, summed the deviations for all indicators, and finally divided by four (the number of indicators). As a result, the four factors were weighted equally. They used regression analysis to compare the index to per capita GDP in 31 industrial nations in 1970 and 1985. The regression line fitted to the cross-sectional data in both years had a positive slope, even though the slope for the 1985 data was less steep. No information was given to show whether the results satisfy any standard criteria for statistical significance. They drew the conclusion that a substantial 'delinking' appeared between material inputs and economic growth. However, some eastern European nations experienced increasing IU, while Japan and Norway experienced overall economic growth that 'canceled' the improvements in the material IU (Cleveland & Ruth, 1998: 26-27).

Jänicke and colleagues (1997) expanded their index to involve more metals, some minerals, petroleum products, and agricultural chemicals. They compared this index to per capita GDP in 32 nations in 1970 and 1991. They found evidence that IU generally falls with rising income for some materials (cement) but rises for others (paper). They concluded that a general decline in materials and pollution-intensive industries 'has not so far become evident in the advanced industrial countries'. In country-specific studies, Jänicke and colleagues found that data for the US provide only 'partial confirmation' of dematerialization, such as steel, aluminum, and cement declined relative to GDP, while paper increased (Cleveland & Ruth, 1998: 27).

Some researchers claimed that the link between income and environmental degradation in terms of derived materials inputs and pollution levels may take an N-shape rather than an inverted U-shape, exhibiting a 'delinking' of environmental degradation from economic growth in relation to rising per capita incomes. Since delinking may not be persistent; some advanced economies may be entering a new period of "relinking". That is, the relationship between environmental degradation and welfare in the medium long term may be N-shaped rather than inverted U-shaped (de Bruyn & Opschoor, 1997: 255). De Bruyn and Opschoor (1997) questioned the empirical results of Jänicke and colleagues (1997) about long-run economic changes which is based on two time periods (1970 and 1985) only. At the same time, they argued that Jänicke and colleagues did not separate between the effects of changes in material intensity and changes in aggregate economic growth on the demand for materials. They repeated Jänicke and colleagues' analysis with data over the period 1966-1990 for 19 nations. They concluded that most nations exhibited 'delinking' from 1966 to 1984, while some developed nations exhibited 'relinking' in the late 1980s (experienced increasing energy and material intensity as a function of GDP). Their empirical findings suggested the existence of an N-shaped pattern rather than an inverted U-shaped relationship (Cleveland & Ruth, 1998: 27; Jaunky, 2012: 297).

Guzmán et al. (2005) concluded that there are two main reasons why intensity of metal use changes over time. The former, new production technologies, long-run price trends, and other forces can alter the *material composition of products*, which is the mix of metals and other materials used to produce specific goods and services, i.e., the development of fiber optics has declined the copper used by the modern telecommunications industry per unit of output. The latter, changes in consumer preferences can alter the *product composition of income*, which is the mixed of goods and services produced by the economy, i.e., the rise in the service sector at the expense of manufacturing in many developed nations has reduced the intensity of use for copper and other metals. The product composition of income for a nation evolves with economic development as a consequence of shifts in comparative advantage and changes in the nature of imports and exports, i.e., at early stage of industrialization, nations with open economies tend to export traditional manufactured products, which are metal intensive, import services and higher technology products. As economic development advances and per capita income rises, a shift in the opposite direction often takes place.

Many researchers argued that the debate over the environmental Kuznets curve might appear as a result of the "path to sustainability", as the way to live in harmony with the environment. The question of how to achieve this harmony has long been examined in the literature. For instance, Beckerman (1992) suggested that 'in the end the best and probably the only-way to attain a decent environment in most countries is to become rich'. Also, Barlett (1994) argued that 'existing environmental regulation, by reducing economic growth, may actually be reducing environmental quality' (Andreoni & Levinson, 2001: 270). Moreover, Panayotou (1993) concluded that economic growth appears to be a powerful way for improving environmental quality in developing nations. That is, environment needs no particular consideration, either in terms of domestic environmental policy or international pressure and/or assistance; this is because resources could be efficiently allocated in order to achieve rapid economic growth to move quickly from the environmentally unfavorable stage of development to the environmentally favorable range of the Kuznets curve.

There has been a wide consensus that the relationships among inputs, outputs as well as the overall effects of economic activity on the environment have been continually changing. The basic thought is that greater economic activity inevitably hurts the environment is based on static assumptions about technology, preferences, tastes and environmental investments. That is to say, as population and income increase, a growing economy will require more inputs (thereby depleting the earth's 'sources') and will produce more emissions and wastes (thereby overburdening the earth's 'sinks'). As the scale of the economic activity increases, the earth's 'carrying capacity' will be surpassed. However, there are several factors that tend to reduce environmental degradation per unit of activity can more than compensate for any negative consequences of the overall growth in scale (World Bank, 1992, p. 38):

- *Structure:* the goods and services produced in the economy
- *Efficiency:* inputs used per unit of output in the economy
- *Substitution:* the ability to substitute away from resources that are becoming scarce.
- *Clean technologies and management practices:* the ability to reduce environmental damage per unit of input or output.

In line with this, the concept of "sustainable development" (SD) replaced the concept of "Limits to Growth" (LTG) in the early 1970s. The concept was indeed introduced in 1980, but popularized in the 1987 report of the World Commission on Environment and Development (the Brundtland Commission), and finally given a global mission status by the UN Conference on Environment and Development in Rio de Janeiro in 1992 (Dincer & Rosen, 2004: 4). Sustainability is "to fulfill "the needs of the present without compromising the ability of the future to meet its own needs" in a system". Since mankind's dominance of the planet, it has become a fashionable word among the scientists, researchers, scholars, authors and the general public. Thus, the concept has turned into a broad area including different levels of human activities and knowledge regarding three major principles of: "Environment", "Economy", and "Society" (see Fig. 5) (Vadiati & Kashkooli, 2011: 829-830).

Fig. 5. The Building Blocks of Sustainable Development [Source: Vadiati & Kashkooli, 2011, p. 830].

Some researchers argued that sustainable development is indeed a necessarily political act, provides the conservation about what kind of world we want to live in today and in the future, rather than a set of future conditions of society or a process of moving toward some predetermined way of thinking (Bolis et al., 2014: 7-8). Others argued that in the 29 years since it was introduced, this concept has been weakened and misinterpreted (Lorek & Spangenberg, 2014: 34). Statistical evidence has shown that: we did not manage to reach a feasible compromise between the two contrasting objectives, preserving the existing ecosystems and meeting the economic needs. While we are growingly demands for a truly sustainable society, our lifestyles are growingly more unsustainable. We will not leave the world better than we find it, we do not respect the planetary boundaries, we take more than we need, we harm the environment, we do not make amends; unless we act very soon, it will be too late to shut down or reverse some of the key indicators included in the environmental crisis.

Many researchers argued that an EKC-pattern might appear as a result of "international trade". The central view is that trade openness fosters the expansion of an economy through increased production of pollution-intensive goods to promote its exports, but at the same time higher production generates more pollution. As income and environmental degradation grow heavily, more severe environmental regulations are imposed on the economy which results in a shift of its domestic production of pollution-intensive goods to other. That is, the exports of goods in a developed nation create the upward slope of its EKC, whereas its imports of goods from developing nations create the downward slope of its EKC. This is known as the 'pollution haven hypothesis' (PHH) (Kaika & Zervas, 2013a: 1395).

Many researchers found a significant effect of international trade on pollution levels. Suri and Chapman (1998) reported that the inclusion of trade effects raises largely the turning point for pollutant emissions related to energy use. Industrializing nations raise the consumption of energy required for the production of goods that are exported to industrialized nations, while industrialized nations lower their energy requirements due to imports of manufactured goods from the industrializing nations. Using data on North-South trade flows for pollution intensive products, Cole (2004) found an evidence of pollution haven effects, but such effects are relatively small compared to the roles played other explanatory variables in the regression. Also, a majority of researchers found an evidence that there are significant differences in traded goods between developing and developed nations (Kaika & Zervas, 2013a: 1395). Industrialization process in the developing nations depends to a considerable extent on the activities of small and medium-scale enterprises (SMEs), which tend to be concentrated in the most environmentally damaging activities (chemicals, textiles, leather and fur products, food processing, non-ferrous metal work, charcoal and fuel wood supply), and tend to depend on older technologies (i.e., difficult to regulate and face fewer incentives not to pollute) (Perrings & Ansuategi, 2000: 23-24). For example, highly polluting industries are typical of the poorest states in USA, while high-income states are oriented towards services and high-tech industries. This trade-specialization between these states explains the variations in their emissions (Kaika & Zervas, 2013a: 1395).

Others argued that the effect of international trade on environmental quality is ambiguous. Using data on seven oft-studied pollutants, Kearsley and Riddel (2010) did not find sufficient evidence that pollution havens play an important role in shaping the EKC. Actually, trade contributed to increased emissions at a decreasing rate as income increased, but only over certain periods of time. Or alternatively, pollution havens might have a transient effect on environmental degradation similar to the effect of low-wage havens on the pattern of comparative advantage (Kaika & Zervas, 2013a: 1395). Using US trade data from 1958 to 1994 to study trends in dirty and clean trade, Kahn (2003) found no evidence that dirty (pollution-intensive) trade increased. But, one piece of evidence that confirmed the pollution haven hypothesis is that the average African nation is exporting energy intensive goods to the US. In the Southern Africa Customs Union (SACU) case, Nahman and Antrobus (2005) detected PHH consistent behavior in the leather industry for the USA-SACU trade pair and in the wood as well as chemicals industries for the UK-SACU trade pair throughout the period investigated. However, there might be a more general shift in manufacturing from the developed to the developing nations, rather than a shift only in pollution-intensive industries as the PHH would seem to imply. In the European Union (EU) case, Cave and Blomquist (2008) pointed out mixed results depending on the definition of industry dirtiness; imports of energy-intensive goods from poorer nations seem to rise when more stringent environmental standards are adopted in the EU, but this is not the case with respect to toxic-intensive imports.

Many authors argued that an EKC-pattern might appear as a result of "foreign direct investment" (FDI) (Bo, 2011: 1324). The basic thought is that foreign direct investment (FDI) inflows are generally expected to promote host nations' economic growth by rising capital accumulation and productivity, which in turn explains, not unexpectedly, why many developing nations are eager to attract more FDI. Despite its potential contributions to economic growth, the rise in the FDI inflows leads to a debate on its potential effects on the environmental quality, environmental standards as well as cross-border environmental performance. Therefore, two opposite views appear regarding the nexus between FDI and the environment: "Pollution Haven Hypothesis" (PHH) and the "Pollution Halo Hypothesis" (Pazienza, 2015: 55-56; Seker et al., 2015: 347-348).

Some researchers confirmed the pollution haven hypothesis (PHH). They argued that different environmental regulations among nations affect the location decisions of the firms or industries. As a result, multinational companies (MNCs), mostly in pollution-intensive industries, tend to migrate from developed economies to developing ones where the environmental standards are less stringent (Seker et al., 2015: 348). This strategy might degrade the environment in the host nation if the issue is not taken seriously (Kivyiro & Arminen, 2014: 596). Jensen (1996) and Acharyya (2009) found that although FDI contributed to better economic growth, it generated more industrial pollution as well as environmental degradation. In order to reduce cost on environmental controls, polluting industries and businesses might tend to be shifted to underdeveloped regions where environmental standards are relatively low, and turn these regions into pollution slums (Lau et al., 2014: 491). Wang (2012) and Cole and Elliott (2005) found that FDI had a positive effect on CO_2 emissions where pollution-intensive industries were more likely to move from developed to less developed economies because the environmental rules and regulations in the less developed economies were relatively weak (Tang & Tan, 2015: 447).

Other researchers confirmed the pollution halo hypothesis. They focused on environmental performance of foreign firms relative to domestic counterparts, rather than industry location. As a result, the presence of foreign investors would spur positive environmental spill-overs to the host nation; this is because multinational companies (MNCs) have more environmental management systems and advanced technology than their domestic counterparts and will tend to disseminate cleaner technology that will be less harmful to the environment (Kivyiro & Arminen, 2014: 596; Seker et al., 2015: 348). List and Co (2000), Mielnik and Goldemberg (2002), and Perkins and Neumayer (2008) concluded that the inflow of FDI stimulated an improvement in environmental quality due to the enhancement of energy efficiency (Lau et al., 2014: 491). Al-mulali and Tang (2013) found that FDI reduced the level of pollution by bringing in advanced and environmental friendly technologies from developed to less developed economies (Tang & Tan, 2015: 447).

Contrary to all empirical studies, the effect of foreign direct investment (FDI) on environmental quality is uncertain. Shahbaz et al. (2015) found that the empirical findings were sensitive to different income groups and regional analyses. In the high-income panel, the linear and nonlinear terms of FDI were negatively linked to CO_2 emissions, which supported the *pollution halo hypothesis*. In the middle-income panel, the linear and nonlinear terms of FDI had opposite signs with statistical significance at 5% and 10% level, respectively. It implied that FDI initially degraded the environment but then improved environmental quality after a certain level. In the low-income panel, FDI and environmental degradation were found to be positively related, as indicated by both the linear and nonlinear terms of FDI. In the case of six Sub Saharan African nations, Kivyiro and Arminen (2014) found that EKC-pattern was more likely to hold at nations having low levels of economic development. Also, FDI appeared to increase CO_2 emissions in Kenya and Zimbabwe (which supported the pollution haven hypothesis), whereas the opposite effect can be observed in DRC and South Africa (which supported the halo effect hypothesis). They concluded that the differences in the nation results might be attributed to the economic structures of each economy. Fig. 6 indicates the conflicting dynamics of the EKC curve.

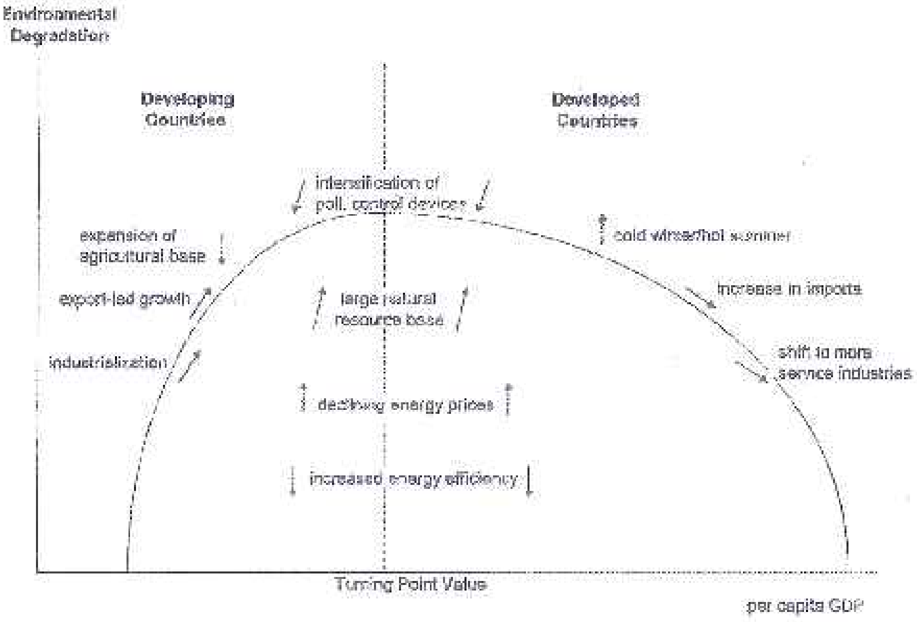


Fig. 6. Conflicting Dynamics of the EKC Curve [Source: Agras & Chapman, 1999, p. 275].

Many researchers supported that three fundamental driving forces of an EKC-pattern are "scale effect", "composition effect" and "technique effect". In the infant stages of development, pollution is generated as a result of increasing production and extraction of natural resources. This is known as the *scale effect* of production on environment. The scale effect creates the upward trend of an EKC when production shifts from primary production to industrial production. At this stage, economic development gives the opportunity of investing in information-based industry and services as well as improving production techniques or adopting upgraded new and cleaner technology. These are known as the *composition effect* and *technique effect* respectively (Kaika & Zervas, 2013a: 1395-1396).

The composition effect (structural change) reflects any shifts in production patterns from the more material and energy-intensive manufacturing sector towards the assumingly more environmentally-friendly services sector. Usually, pollution is generated as the composition of production shifts from light industry (agriculture or textile) to heavy industry (minerals, chemical, machinery, etc.), and subsequently, shifts towards information-based industries and services which are characterized as less-polluting, or any other qualitative reformation of the economic structure (Kaika & Zervas, 2013a: 1396).

The technique effect (technical progress) reflects improvements in technology that encourage the use of less inputs per unit of output or the adoption of upgraded new and cleaner technologies that substitute the obsolete and dirtier technologies in the production of goods. Also, the development of cleaner techniques is promoted by investments in environmental R&D for which, a sufficient level of economic growth is required (Kaika & Zervas, 2013a: 1396). In conclusion, the shape of the EKC reflects that the negative impact on environment of the scale effect that tends to dominate in the infant stages of development, but it will eventually be outweighed by positive impact of the composition and technique effects that tend to lower the emission level (Dinda, 2004: 435-436). Fig. 7 indicates these effects on EKC-pattern.

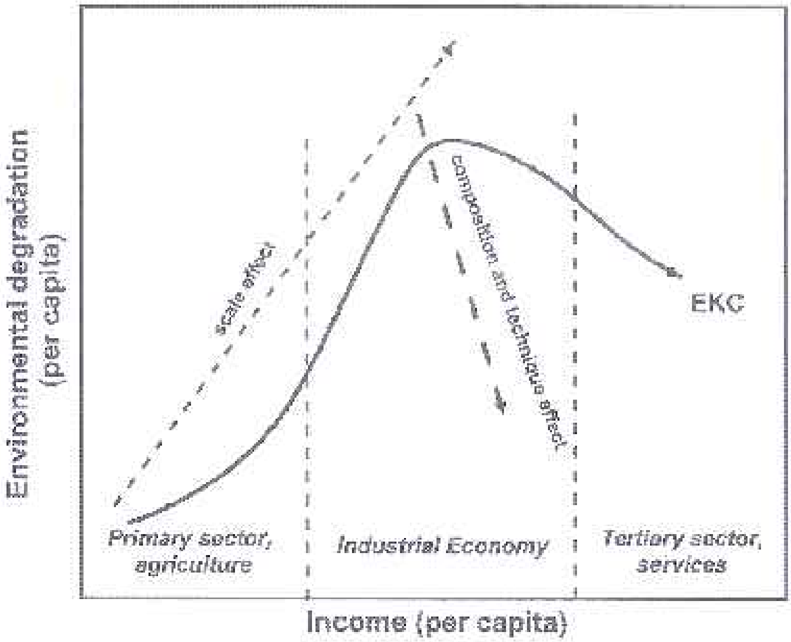


Fig. 7. Scale, Composition and Technique Effect on EKC [Source: Kaika & Zervas, 2013a, p. 1396].

Some researchers argued that advances in technology over time seem to be the major factor of improved environmental quality (Kaika & Zervas, 2013a: 1396). Using data on three types of emissions (CO_2, NO_x, SO_2) in four nations (Netherlands, UK, US, Western Germany), De Bruyn et al. (1998) found that emissions may have decreased over time probably as a result of structural and technological changes and not as a result of economic growth. Dinda et al. (2000) concluded that observed changes in pollution levels over time or across region can be attributed to shifts in production techniques and to sectoral-output composition with respect to SPM and SO_2. Concerning industrial water pollution, Hettige et al. (2000) used as explanatory variables the share of industry in total output, the share of polluting sectors in industrial output and "the end-of-pipe" pollution intensities per unit of output in the polluting sectors. They found that only the industry share of national output follows a Kuznets-type trajectory.

Others argued that structural and technological changes have a transient effect on pollution mitigation. Grossman and Krueger (1995) found that improvements in indicators of urban air quality might result from technological innovation, but this result reflects specific technological, political and economic conditions of the time under investigation. Dinda (2010) found that an EKC-curve might reflect the cycle of diffusion-externality generation-innovation of each new technology in the short-run, and that nonlinear EKC envelopes a series of EKCs corresponding to different and subsequent technologies in the long-run (Kaika & Zervas, 2013a: 1396). Smulders and Bretschger (2000) used as three key variables technological change, intersectoral shifts and policy changes. They indicated that the government forces companies to use innovative technology (general purpose technologies, GPT) to reduce pollution under the environmental pressures. The arrival of innovative technologies would generate changes within the department structure, which was known as 'intersectoral shifts'. But, many companies would be reluctant to use clean GPT and keep polluting GPT, therefore affect the quality of the environment. While the arrival of innovative technology is expensive, slow diffusion as well as high uncertainty, a technological breakthrough is highly uncertain and arrives, if ever, unexpectedly (Yin et al., 2015: 99).

Many researchers have investigated the significant effect of technology and structural changes on both CO_2 and SO_2 emissions over time. The key factor of their studies is the evolution of "energy intensity" over time and particularly the shifts in energy mix and in conversion efficiency (Kaika & Zervas, 2013a: 1396). Energy intensity (EI) is referred to "the energy needed to produce one unit of gross domestic product, is generally expressed as the ratio between primary energy consumption (e.g. tons of oil equivalent or MJ of Gross Energy Requirement) and the GDP (e.g. international – purchasing power parity – real dollars)" (Fiorito, 2013, p. 466). In particular, this concept was seen as a crucial matter after the oil crises in the 1970s that led to a general concern about energy conservation. Thus, the structure of the oil-depended economies had to be transformed with the adoption of upgraded new techniques that would lower the energy-intensity per unit of output as well as the reinforcement of the service sector that is based on a lighter productive structure (Kaika & Zervas, 2013a: 1396).

There are two main reasons to perform energy EKC studies. The first reason is the link between energy consumption and economic growth; more specifically, higher economic growth reflects higher energy consumption, directly associated with the 'biophysical constraints' (Zilio & Recalde, 2011: 7943) or 'limiting factor' to economic growth. On one hand, energy is a vital and necessary input along with other factors of production. Thus, energy is a necessary requirement for economic and social development (Chontanawat et al., 2008: 210). On the other hand, energy supply imposes boundaries to economic growth as a result of the role of energy in the production process, the no reproducibility of energy resources, boundaries to within substitution, and limits to the substitution of other factors of production by energy. This case generated an extensive number of studies to evaluate empirical evidence testing Granger causality and cointegration models, which still have not provided clear outcomes (Zilio & Recalde, 2011: 7943).

The second, and probably the most powerful reason is the link between energy consumption and environmental pollution (Zilio & Recalde, 2011: 7943). According to European Environment Agency (2015), the most significant sectoral source of SO_2 emissions was energy production and distribution (58% of total emissions), followed by emissions occurring from energy use in industry (%20) and in the commercial, institutional and households (15%) sector. According to Joint Research Centre (2015), energy-intensive activities are of the highest relevance for CO_2 emission trends, and fossil-fuel combustion accounts for 90% of total CO_2 emissions, excluding those from deforestation and other land uses. Power generation remains the most important sector with respect to fossil-fuel consumption, thus the power sector's choice to use fossil fuel is of the utmost importance.

Many researchers have dealt with the evolution of energy intensity over time. Agras and Chapman (1997, 1999) analyzed previous models to show the importance of prices in these models and then included prices in an econometric EKC framework testing energy/income and CO_2/income relationships. These long-run price/income models showed that income is no longer the most relevant indicator of environmental quality or energy demand. The researchers found no significant evidence for the existence of an EKC within the range of current incomes for energy in the presence of price and trade variables. Yang et al. (2016) found that the energy price index has the least impact on energy intensity. They asserted that policy measures aimed at both deepening the energy price reforms and decreasing price distortions can be appropriate for continuously improving energy efficiency, preventing the rise in energy consumption as well as energy intensity. Stern (2004) concluded that energy intensity per unit of output has fallen over time due to a shift from the direct use of fossil fuels to the use of higher quality fuels and electricity. Such changes in fuel-mix are associated with technological innovations (Kaika & Zervas, 2013a: 1397).

Some researchers argued that changes in energy intensity are not common in all nations (Kaika & Zervas, 2013a: 1397). Hamilton and Turton (2002) showed that the large fall in the energy intensity of OECD economies over the period 1982-1997 has been driven primarily by falling energy intensities in the services and industry sectors of the USA and the services sector of the EU, but these have been offset somewhat by rising energy intensity of services in Japan. Mielnik and Goldemberg (2000) visually inspected the intensity paths of 41 nations over 1971-1992, and found that their 18 developed nations were on a decreasing trajectory, but that their 23 developing nations were following an increasing trajectory (Liddle, 2010: 3218). Liddle (2010) concluded that four main factors explain energy intensity differences across nations: firstly, economic structure (the share of energy-intensive industries in total economic output); secondly, sectoral composition of energy use (the relative shares of different end-uses including industry, buildings, and transport); thirdly, fuel mix; and finally, efficiency in the conversion and end-use of energy.

Other researchers used a number of measures, primarily developed in the economic growth literature, to determine whether nations' energy intensity levels are converging (cross-country differences are declining) at both the world and regional levels. Smil (2003) showed that large inter-country differences in energy intensity tend to expire when output is measured on a purchasing-power-parity basis (Fiorito, 2013: 466). Markandaya et al. (2006) used an economic growth-type convergence equation, and found that from 1992 to 2002 the energy intensity of several transition nations of Eastern Europe converged toward the levels of the European Union (EU) average. Miketa and Mulder (2005) examined energy-productivity convergence (the inverse of energy intensity) across 56 developed and developing nations in 10 manufacturing sectors, and found that differences across nations tended to decline, particularly in less energy-intensive sectors. Also, Liddle (2009) examined electricity intensity in OECD nations at various levels of sectoral aggregation and discovered that commercial electricity intensity is converging toward a bell-shaped distribution, while industry electricity intensity is converging toward a bimodal one. The OECD nations converging toward the higher level of industry electricity intensity are more concentrated in the most energy-intensive sub-sectors (minerals, mining, pulp and paper), while the 12 nations converging toward the lower level of industry electricity intensity reflect substantial heterogeneity in industrial structure (Liddle, 2010: 3218).

Some researchers dealt with the microeconomic implications of "consumer preferences" as a partial explanation of an EKC-pattern. The most common question for the shape of the EKC-pattern is how the consumer's preferences with respect to environmental quality shift when their income changes. That is, changes in income alter the elasticity of demand for environmental quality η which is represented as: $\eta = \frac{(\Delta E)\%}{(\Delta Y)\%} = \frac{\theta E}{\theta Y}\frac{Y}{E}$, where E is the quantity of environmental good demanded and Y is income. Hence, the income elasticity of demand for environmental quality η is the change in the demanded quantity of environmental quality with respect to a change in income. If $\eta > 1$, then E is a "luxury good" and, if $\eta < 1$, E is a "normal good". Although it is difficult to measure E, most researchers assumed that $\eta > 1$ treating clean environment and preservation as 'luxury' goods (Kaika & Zervas, 2013a: 1397).

In addition, there exists an alternative approach is to measure the income elasticity of the *Willingness to Pay* (*WTP*), which accounts the change in the willingness to pay for some environmental quality in response to a change in income. Most studies demonstrated that the income elasticity of willingness to pay is less than unit, whereas the income elasticity of demand on environmental quality is marginally over unit (Kaika & Zervas, 2013a: 1397).

Many researchers have dealt with the changes in consumer preferences with respect to environmental quality over time. Kander and Lindmark (2004) found that environment in Sweden was appreciated at a higher value after the 1970s, which gave rise to willing action to prevent further pollution; as a result, environmental quality was upgraded. In contrast, with respect to Italian households' consumption expenditures, Martini and Tiezzi (2014) consistently found that the income elasticity of willingness to pay for environmental quality is very close to unity for all income groups suggesting that getting richer does not necessarily bring cleaner environment (Kaika & Zervas, 2013a: 1397). Carlsson and Johansson-Stenman (2000) found that willingness to pay for improved air quality was increasing in income, wealth and education; it was larger for men, members of environmental organizations, citizens living in big cities which are on average more polluted, and citizens who own their house or apartment, but was lower for retired citizens. Wang et al. (2015) found that parents in Shanghai would be willing to pay for improved air quality. The amount of willingness to pay offered by the parents of relatively unhealthy children was higher than that of the other ones.

Therefore, different preferences shape different consumption-patterns, which need different abatement policies, while the awareness of an environmental issue takes a long time. Even if when such a problem is determined, the undertaken actions depend on the utility of the agents, their relative economic position and their spatial ability to separate themselves from the source of pollution. All in all, the income-pollution issues has been considered as a macroeconomic subject along with any microeconomic foundations of this relationship in itself, and thus are difficult to be detected in a sufficient way (Kaika & Zervas, 2013a: 1397).

Investigating the microeconomic implications of consumer preferences on the environment is a challenging task. For instance, appropriate preferences can generate an EKC-pattern for all pollution functions, however there is no guarantee that such appropriate preferences exist. If consumers do not exercise enough environmental struggles as they become wealth, then the most sophisticated and effective abatement technologies cannot prevent pollution from increasing. However, consumers do not need to have very 'green' preferences for pollution to ultimately fall with income if abatement becomes sufficiently effective (Plassmann & Khanna, 2006: 634-643). Furthermore, it is difficult to estimate the effect of a shift in consumers' preferences, since such shift might depend on various spatial and time conditions, i.e., inhabitants of a city where consumption is concentrated might not need concern themselves with the negative health effects of a waste treatment installation located in a sparsely populated area, or even across a great distance, when the cost of pollution could be transferred to a remote future. In such cases, the inhabitants have few incentives to alter their consumption patterns or change the composition of these patterns, unless they sincerely concern about the effects of environmental degradation to others (Kaika & Zervas, 2013a: 1397).

Many researchers argued that an EKC-pattern is not formed in isolation from political institutions that related to the process of environmental policy making in a nation (You et al., 2015: 189). A central view is that as an economy grows, its government is expected to respond properly to public awareness on environmental degradation and to countervail market failures by imposing proper regulations that prevent further pollution from increasing. As a result, the growth of an economy is a necessary condition to counteract pollution but it is not a sufficient condition alone. (Kaika & Zervas, 2013a: 1397). Whether improvements of environmental quality or curtailed environmental degradation materialize or not, when and how depend critically on government policies, social institutions and the completeness as well as functioning of markets (Panayotou, 1997: 468). Although it seems easy applicable from a theoretical point of view, in practice it is difficult to accurately evaluate the effectiveness or ineffectiveness of a nation's governance or of its political institutions that would enable a better estimation of their impact on environmental degradation (Kaika & Zervas, 2013a: 1397).

Li and Reuveny (2006) as well as Bernauer and Koubi (2009) surveyed the literature about the positive and negative effects of democracy on environmental quality. Five theories have been formulated to support democracy as an "improver of environmental quality" (Hosseini & Kaneko, 2013: 313). A first argument assumes that political rights and freedom of information encourage the birth of environmental interest groups, which raise public awareness and promote environmental legislation. This effect applies through environmental groups and public opinion at large. That is to say, information on environmental problems flows more freely, and political rights are more various as well as better protected in a democracy than in an autocracy. Consequently, environmental groups are often more effective in informing citizens and organizing them to act on environmental problems in a democracy than in an autocracy (Li & Reuveny, 2006: 936-937).

The exact opposite situation is that the autocratic regime censors information flows (environmental degradation might not be reported by the media to the citizens), and its decision making is more autonomous than that of a democratic government. In reality, the elite in an autocracy might be more educated than the public as education tends to develop with income, ceteris paribus. However, as democracy provides free media, environmental problems are more likely to be reported by the media to the citizens. In other words, citizens in democracy are more likely to be informed about the health of the environment than are members of the elite in an autocracy (Li & Reuveny, 2006: 937), and therefore they express their preferences for environment (freedom of expression) and put pressures on their governments as well as generate lobbying groups (freedom of association) (Romuald, 2011: 3).

A second argument assumes that democracies are more responsive to the environmental needs of the public than are autocracies. This effect applies through electoral accountability and the ability of groups to mobilize socially, perform political representation as well as affect public policy making. A central view is that democracies hold regular and free elections, which can bring to power new parties that are characterized as friendly to the environment. In contrast, the distribution of political power in an autocracy is concentrated, thereby restricting the likelihood that environmentalists will come to power. As a result, environmentalists stand a greater chance of influencing policy making in a democracy than they do in an autocracy. At the same time, this view might reflect that citizens could freely elect extreme anti-environmental parties although causal observation shows that such cases do not occur frequently in reality (Li & Reuveny, 2006: 937).

A third argument is closely related to institutional and ideational features of democracy. The main speculation is that democracies are more likely to comply with environmental agreements because they respect the rule of law and human life (fewer wars and famines), support economic freedom and market economies, which in turn raises environmental quality (Hosseini & Kaneko, 2013: 313; Li & Reuveny, 2006: 937). Gleditsch and Sverdrup (2003) argued that democracies are more responsive to life-threatening environmental degradation than autocracies as they respect human life, and also that democracies engage in fewer wars than autocracies as they respect the environmental quality. Moreover, Sen (1994) argued that famines generate more environmental degradation; this is because they divert attention away from long-run environmental concerns. Thus, famines and environmental degradation is more likely to be higher in autocracies than in democracies because democratic governments are more responsive to the needs of the citizens and environmental protection (Li & Reuveny, 2006: 937).

A fourth argument assumes that the elite in an autocracy will be less pro-environment than the masses and/or the public at large in a democracy. With the prevailing technologies and materials, the implementation of stricter environmental policies can lower the levels of production, income and consumption, which, in turn, impose a higher cost on the elite in an autocracy than on the population while the marginal benefit is uniform for both the elite and population (Li & Reuveny, 2006: 937; Romuald, 2011: 3). The logic is as follows: the elites use the resources of their respective nation to generate personal wealth and to redistribute income from their populations towards themselves. If the costs of stricter environmental policies are inherent disproportionately by the elites, as it would be the case with restrictions on polluting industrial activities, while the benefits are uniformly dispersed throughout the population, then these elites would have little incentive to adopt and implement such policies. In contrast, in democracies the median voter, who elects public policy, faces lower costs from environmental policies relative to the economic and political elite. In short, this makes the adoption and implementation of stricter environmental policies more likely in democratic regimes (Bernauer & Koubi, 2009: 1356).

A fifth argument assumes that the discount rate and the time horizon of the government force are important factors in solving many forms of environmental degradation that develop slowly and over long periods of time (i.e., climate change, biodiversity, air and water pollution, etc.). The masses in a democracy should have less at stake over regime change than the elite in an autocracy. The elite in an autocracy are tightly related to the leader, i.e., if the leader loses power, the elite might suffer heavy losses or even lose their lives. Facing this possibility, the elite might wish to prevent regime change by force, i.e., if they invest more today to silence real or potential rebels, they will allocate resources away from environmental problems. Also, the elite might suppose that the change is inevitable or hedonic, i.e., if they consume more today, they will ignore environmental degradation that takes a long time to amend or current activities that will cause damages in the future. Both cases rise the discount rate and reduce the time horizon of the autocratic government force. And, consequently, the ruling elite in an autocracy is more likely to ignore environmental degradation expected in the future (Li & Reuveny, 2006: 937-938).

In contrast, four theories have been formulated to indicate that democracy might not reduce environmental degradation or might even increase it depends on several mechanisms (Hosseini & Kaneko, 2013: 314; Li & Reuveny, 2006: 938). A first argument assumes that when private property rights of natural resources are not well defined, as is often the case with 'the commons'" (i.e., clean air, oceans, forests, and habitable earth), free (unconstrained) individuals or interest groups tend to over exploit such resources and ignore the damage that their economic actions inflict on the environment (Li & Reuveny, 2006: 938). Hardin (1968) noted that:"freedom in a commons brings ruin to all" (p. 1244), since "we are locked into a system of 'fouling our own nest,' so long as we behave only as independent, rational, free-enterprisers" (Hardin, 1968, p. 1245). Gleditsch and Sverdrup (2003) concluded that: "Hardin's 'Tragedy of the Commons' does not encourage confidence in the effect of economic and political freedom on environmental quality" (Li & Reuveny, 2006, p. 938).

A second argument assumes that the nature of environment and democracy are different. Environment is a "global phenomena" while democracy functions on only national and local decision levels. Thus, global environmental problems might not necessarily be attended to in a timely manner. For instance, Heilbronner (1974) argued that global population growth threatens global environmental quality. Being autonomous decision makers, autocracies can curtail human reproduction, while democracies are held accountable by the public, and thus respect citizen rights, including those involving human procreation (Hosseini & Kaneko, 2013: 314; Li & Reuveny, 2006: 938; Romuald, 2011: 4).

A third argument assumes that democracies tend to be market economies, where business interest and/or lobbying groups have considerable clout. The basic thought is that the asymmetric influence of profit-oriented corporate interests in capitalist democracies. Consequently, democracies are not regarded as protecting environmental quality as they are expected to satisfy the preferences of markets and business interest and/or lobbying groups which aims at maximizing their economic profit that is not favour of a better environmental quality (Hosseini & Kaneko, 2013: 314; Li & Reuveny, 2006: 938; Romuald, 2011: 4).

In addition, the influence of business interest and/or lobbying groups is in part responsible for institutional *sclerosis* in mature democracies. The logic is as follows: as democratic societies become more advanced and stable, their institutions become more complex, and therefore stability might turn into rigidity at some point. Since, in mature democratic systems public goods provision could suffer from the existence of a relatively large number of business interest and/or lobbying groups that have little or no incentive to make significant sacrifices in the interest of society as a whole. Therefore, these groups compete over access to and control over legislative as well as administrative processes in an attempt to appropriate larger shares of a society's production, which, in turn, fall short of improving environmental quality (Bernauer & Koubi, 2009: 1357).

A fourth argument assumes that democratic governments are more sensitive to the economic concerns of the majority of the voting public. By implication, this implies that when the majority is expected to lose more from environmental policies, democracies become reluctant to mitigate environmental degradation (Hosseini & Kaneko, 2013: 314; Li & Reuveny, 2006: 938). Also, the governments are elected for a limited time period as a rule. This case might probably deter a government, due to the potential political cost, from imposing environmental regulations that protect the environment from market failures that generate long-term externalities, especially pollution. Moreover, when the political system is highly corrupted or less effective, then the agent's willingness to upgrade environmental quality might not be observed by their governments, since corruption affects the process of economic growth. In the same way, if governmental institutions are weaker, less effective as well as more corrupted, then a possible EKC-curve might peak at higher income levels or well above the social optimal income level. Nevertheless, improved governance and/or policy reform in poor nations are sufficient conditions to reverse this situation (Kaika & Zervas, 2013a: 1397).

1.2. A Conceptual and Methodological Critique of the Environmental Kuznets Curve (EKC)

The environmental Kuznets curve (EKC) is referred to as the hypothesis that the relationship between environmental degradation and per capita income reflects an inverted-U shape. The logic of the EKC relationship is rather intuitive: in the infant stage of industrialization, pollution grows rapidly because greater priority is given to increasing material output, and citizens are more interested in jobs and income than in public properties like environment and its resources (clean air and water). The rapid growth inevitably results in greater use of natural resources and emission of pollutants, which in turn put more pressure on environment. In this stage, citizens are too poor to pay for abatement, and/or ignore environmental consequences of growth. At the later stage of industrialization, as income increases beyond a threshold (known as "income turning point"), the willingness to pay for a clean environment increases by a greater proportion than income, and consequently regulatory institutions become more effective in reducing pollution levels generating gradual improvement of environmental conditions (Baek & Kim, 2013: 744; Dinda, 2004: 432; Kijima et al., 2010: 1187; Onafowora & Owoye, 2014: 47).

Even from these narrow and somewhat impressionistic observations, it seems to be the case that EKC hypothesis postulates a well-defined relationship between level of economic activity and environmental degradation, is defined as the level of concentration of pollution or flow of emissions, depletion of resources, and so on. In more formal terms, if we plot per capita income on the horizontal axis of an XY chart and some measure of environmental indicator on the vertical axis, this hypothesis suggests a plot that looks like an upside-down "U". It exhibits how a technically specified measurement of environmental quality changes as the fortunes of a nation or a large human society change. Thus, it is a "statistical artifact" that summarizes a few significant aspects of collective human behavior in two-dimensional stage (Dinda, 2004: 432).

A normal type of EKC has the form displayed in Fig. 8. The relationship between environmental degradation (per capita) and income (per capita) is plotted as an inverted-U and is similar to the original curve suggested by Simon Kuznets (1955) concerning the relationship between income inequality and economic growth. The turning point in Fig. 8 demonstrates the level of income (per capita) beyond which environmental degradation could be de-linked from the process of economic growth. It is clear that economic growth upgrades the environmental quality in higher income levels (Kaika & Zervas, 2013a: 1393-1394).

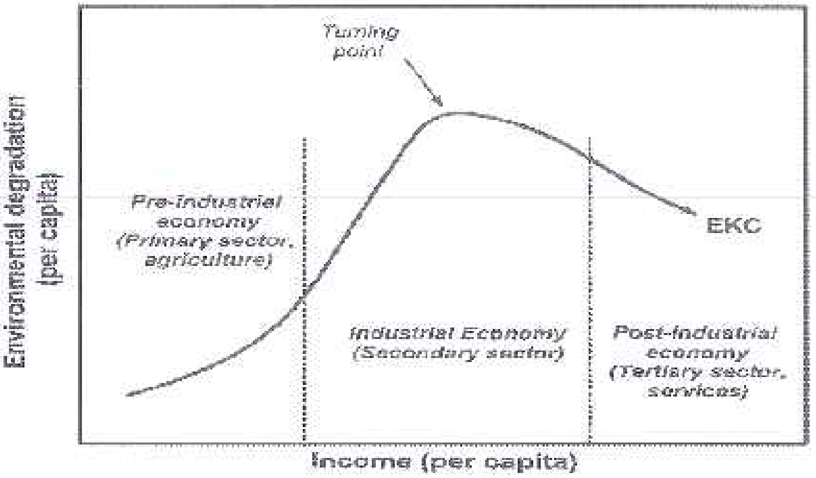


Fig. 8. An Environmental Kuznets Curve (EKC) [Source: Kaika & Zervas, 2013, p. 1394].

In Fig. 8, the dependent variable on the vertical axis is a type of an indicator of environmental degradation. In the absence of a single environmental indicator, it is possible to separate three main categories that have been used in the literature: air quality indicators (sulfur dioxide, suspended particulate matters, carbon monoxide, carbon dioxide, nitrous oxides, lead, and volatile organic compound), water quality indicators (pathogens, heavy metals, and water oxygen regime), as well as various other environmental quality indicators (municipal solid wastes, access to urban sanitation and safe drinking water, deforestation, energy based variables, traffic volumes, toxic intensity or intensity of industrial raw material usage, biological diversity, and endangered species) (Dinda, 2004: 441; Kaika & Zervas, 2013a: 1394-1400; Tutulmaz, 2015: 75-76).

The independent variable on the horizontal axis is a type of an indicator of economic performance. Indicators of economic performance can be represented by income (PPP adjusted income per capita), economic growth (per capita), which is calculated by dividing the Gross Domestic Product (GDP) with the population of the economy, a measure of consumption (private and government consumption per capita), a measure of development (the human development index), and a measure of poverty (an IFAD index of rural poverty in the developing nations) (Kaika & Zervas, 2013a: 1394; Perrings & Ansuategi, 2000: 26).

In the manner of explanatory variables, previous studies have suggested that there is an enormous range of variables as determinants of environmental pollution or degradation. Recently, the focus of attention has shifted from mainly economic (international trade, foreign direct investment, financial openness measuring the extent of openness in capital account transactions, globalization index, the industrial share of total output, the share of individuals working in the industry sector, the composition of a nation's energy sector, the amount of commercial energy used to produce one dollar of output, the GDP per unit of energy use, the share of electricity supply from coal and alternative (non-fossil) sources, the use of fertilizer) to political (the index of economic freedom, political freedom index, civil liberties index, the difference between the sub-indexes for democracy and autocracy, the party of the chief executive has a left-wing orientation, the number of years the chief executive has been in office, being a dictatorship and socialist, economic organization index, control of corruption, being a presidential and parliamentary system, the degree of capitalism, government stability index, bureaucracy quality index, law and order, judiciary independence) and demographic (area, arable land, population, the share of the population in working age, population density, population growth, urbanization, total length of highways, landlocked, absolute latitude, temperature, inequality and education) determinants.

The sufficiency and validity of the Environmental Kuznets Curve hypothesis has generated a controversial debate on both theoretical and empirical grounds. The experimental studies have provided a broad diversity of findings (see table 1), since the empirical results are sensitive to the available information (i.e., the sample of nations chosen and the time period considered), the considered pollution indicators, the proposed functional form and the econometric methodology. The vast diversity of empirical findings has been summarized in some surveys and meta-analyses by He (2007), Jordan (2010), Cavlovic et al. (2000), Bo (2011), as well as Koirala et al. (2011). According to a recent study by López et al. (2014), the Kuznets inverted-U shape is confirmed by 55.7% of the studies while the more flexible N and inverted N patterns seem to be valid in 16.4% and 3.3% of the cases respectively. With regard to the evidence against the EKC, 11.5% of the studies exhibit increasing trends. A synthesis of these results is indicated in Fig. 9 (Pérez-Suárez & López-Menéndez, 2015: 429).

Table 1. Empirical Studies of Environmental Kuznets Curve.

Estimated Pattern	**References**
Inverted U-Shape	Beckerman (1992), Shukla & Parikh (1992), Panayotou (1993; 1997), López (1994), Shafik (1994), Selden & Song (1994), Grossman (1995), Grossman & Krueger (1995), Paudel et al. (2005), Holtz-Eakin & Selden (1995), Cole et al. (1997), Roberts & Grimes (1997), Stern (1998), Kahn (1998), List & Gallet (1999), Bradford et al. (2000), Antweiler et al. (2001), Heerink et al. (2001), Stern & Common (2001), Permann & Stern (2003), Cole & Elliot (2003), Halkos (2003), Milimet et al. (2003), Cole (2003), Canas et al. (2003), Giles & Mosk (2003), Frankel & Rose (2005), Mcpherson & Nieswiadomy (2005), Galeotti et al. (2006), Plassman & Khanna (2006), Deacon & Norman (2006), Azomahou et al. (2006), Culas (2007), Song et al. (2008)
U-Shape	Panayotou (1997), Kaufman et al. (1998), Dinda et al. (2000)
N-Shape	Grossman & Krueger (1991), Shafik & Bandyopadhyay (1992), Moomaw & Unruh (1997),Torras & Boyce (1998), List & Gallet (1999), Barret & Graddy (2000), Bradford et al. (2000), Gangadharan & Valenzuela (2001), Cole & Elliot (2003)
Inverted N-Shape	Gangadharan & Valenzuela (2001), Harbaugh et al. (2002)
Monotonically Increasing	Roca et al. (2001), Stern & Common (2001), Permann & Stern (2003)
Monotonically Decreasing	Shukla & Parikh (1992), Carson et al. (1997), Gale & Mendez (1998)
No Specific Patterns	De Bruyn et al. (1998), Egli (2002)

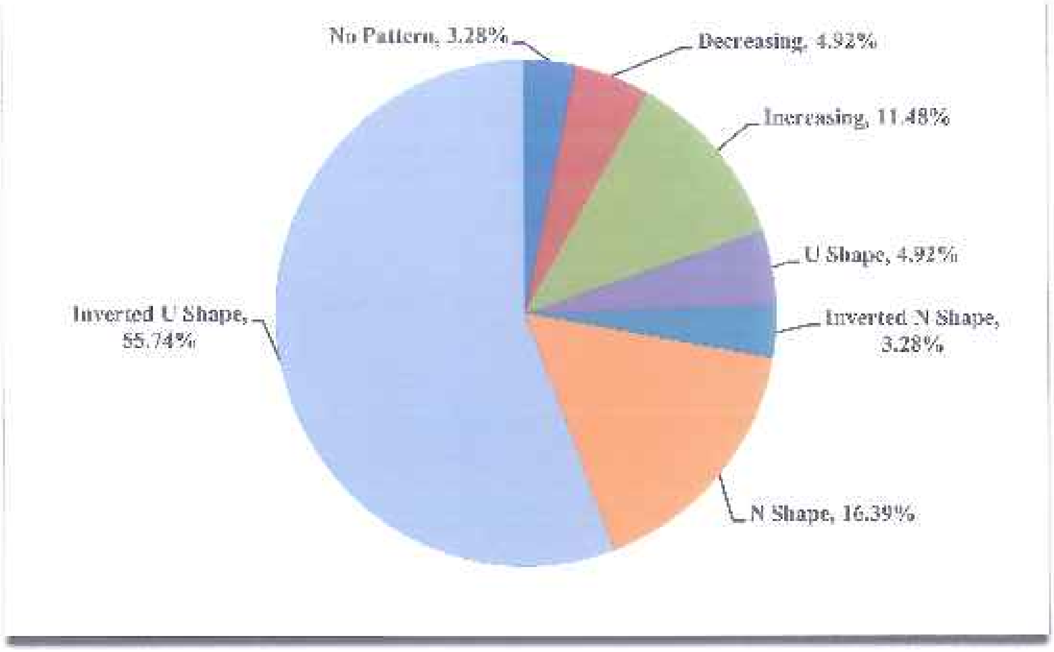


Fig. 9. Empirical Evidence about the Environmental Kuznets Curve [Source: Pérez-Suárez & López-Menéndez, 2015, p. 430].

By these implications, evidence for the EKC hypothesis is mixed. There are three main caveats in the empirical literature. The first and most obvious one is that not all pollutants obey this empirical regularity (Esteve & Tamarit, 2012a: 2696). The EKC relationships are more likely to hold for certain types of environmental degradation, i.e., pollutants with more short-term and local effects, rather than those with more global, indirect and long-term effects. The significant EKCs exist only for local and regional air pollutants (SO_2, SPM, NO_x, CO), and urban air concentrations with a peak at lower income levels than total per capita emissions (Dinda, 2004: 442). In contrast, the global pollutants (CO_2, municipal waste, energy consumption and traffic volumes) seem to fit the original scenario postulated by the Club of Rome group with emissions appearing to increase with income without limit, or at least to some very high level turning point income. Moreover, some of the pollutants (i.e., the levels of aggregate materials consumption) seem to follow the EKC might in fact indicate re-linking at higher income levels with a subsequent upswing again in emissions (showing 'N-curve' rather than "the Kuznets inverted U-curve") (Esteve & Tamarit, 2012a: 2696).

The second caveat is that not all nations obey this empirical regularity. From a theoretical point of view, the EKC seems as a "development path", implying that no effort should be made to adopt environmental policies in developing nations when those nations become rich the current environmental issues will be addressed by policy changes adopted at that later time. It is suggested that developing nations are 'too poor to be green' and that little in the way of environmental clean-up activity is being conducted in those nations (Perman & Stern, 2003: 326). Some policymakers in developing nations and donor institutions misunderstood this path as a proper policy: "Grow first, then clean up" (Dasgupta et al., 2002: 147).

The empirical evidence supersedes the debate about whether all nations follow the same development path. Generally, the EKC is found empirically in some nations, but such results do not guarantee that the EKC is universal and often the inverted-U is accepted for less developed nations. Since, the worldwide emission prospects are not optimistic as it might be assumed on the basis of EKC hypothesis. For instance, the US had long been the world's largest emitter until around 2007 when it was exceeded by China. The US's carbon emissions have declined by 11% for the period 2009 to 2014. But at the same time, the emissions of developing nations grew at a faster rate than that of the rate of decline in industrial nations' emissions, particularly China's carbon emissions grew by almost 50% from 2007 to 2014 (Dong et al., 2016: 210-211).

A possible explanation for such heterogeneity across nations is high-income nations may have moved their emission-intensive industries offshore to developing nations. Suri and Chapman (1998) found that rich nations were growingly importing more energy-intensive products, and therefore the consumption and production of manufactured goods can be separated geographically. This implies that an inverted-U might be observed for the production account for some nations, but none for the consumption account at least two reasons: The former, consumption contributes to the production of 'dirty' goods regardless of where they are produced; the latter, the exporting nations may gain from trade, thus the gains fuel additional consumptions and lead to a higher level of global emissions (Dong et al., 2016: 211).

The third caveat is the scattered diverse evidence found, mainly due to four reasons. First, other factors can also be driving emission levels, including the degree of trade protection, the degree of political freedom (index of civil liberties), and the effect of economic growth (scale of economy) independent of the income per capita level. Second, the probability is that the turning point has not been met yet for some nations and pollutants. Third, many of the EKC studies are conducted on a cross-section nation basis rather than on a more careful panel or time-series framework within specific nations (Esteve & Tamarit, 2012a: 2696-2697). Fourth, the EKC does not necessarily represent a sustainable time path of pollution, since it represents the patterns of flows of pollutants, while environmental effects are often characterized as a stock problem (Dinda, 2004: 447).

In the existing empirical literature, estimated relationships are mainly based on the solution of a structural system of (unknown) equations that generate the final relationship between environmental degradation and income, known as reduced-form equations. Using a reduced-form equation allows researchers to measure directly the effect of income on environmental degradation (Kaika & Zervas, 2013a: 1394). There are two different reduced form equations shown in model (1) and (2). The first model is employed to investigate seven different polygonal forms related to the environment-economic development relationships. The second model has the triple form suggested by Shafik and Bandyophadyay, which includes a time trend term (*time*) to explain the effect of the technology or efficiency changes. However, there is a critical view for using trend in terms of that it might cover the effect of other variables which changes with time (Tutulmaz, 2015: 75).

The following reduced form model is used to test the various possible relationships between pollution level/environmental pressure and income (Tutulmaz, 2015: 75):

$$EP_{i,t} = \alpha_{i,t} + \beta_1 . Y_{i,t} + \beta_2 . Y_{i,t}^2 + \beta_3 . Y_{i,t}^3 + \beta_4 . Z_{i,t} + e_{i,t} \qquad (1)$$

EP: environmental pressure

Y: economic development variable (in terms of per capita income)

Z: other variables

i, t: country and time index

α, β: constant term and coefficient parameters

e: error term

In model (1), *EP* can be represented as some pressure caused by economic development on the environment. *Y* can be represented as income or per capita income which is commonly used in the literature. $Z_{i,t}$ represents other variables that might affect *EP*. *i* and *t* are country index and time index. α is the constant term. β_k is coefficient of *k*th explanatory variable; β_1, β_2 and β_3 are jointly determine the polygonal shape of EKC curve, i.e., inverted-U or N type curve. $e_{i,t}$ represents the normally distributed residuals (Tutulmaz, 2015: 75). Depending on the study, the model (1) can vary. For example, many studies work on a (natural) logarithmic transformation of (1) by using $ln(EP)$ and $ln(Y)$ instead of *EP* and *Y* in order to avoid zero or negative indicators. In any case, the final choice of the functional form is chosen on the model that best fits the available data and has the higher explanatory power inside the data range (Kaika & Zervas, 2013a: 1394).

The model (1) is used to investigate 7 different polygonal forms related to the environment-economic development relationship. Parametric conditions (Diao et al., 2009: 542-543; Tutulmaz, 2015: 75):

i. $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$; a monotonically increasing linear relationship between emission and income.

ii. $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$; a monotonically decreasing linear relationship between emission and income.

iii. $\beta_1 \geq 0$, $\beta_2 < 0$ and $\beta_3 = 0$; a quadratic relationship with opening downward direction, generally described as an "inverted U-shaped curve". Also, this is known as a "conventional EKC" in the literature. Researchers can obtain the turning points at $Y^* = -\frac{\beta_1}{2\beta_2}$ or $Y^* = exp(-(\beta_1/2\beta_2))$, in the logarithmic version, by setting derivatives of equation (1) equal to zero.

iv. $\beta_1 \leq 0$, $\beta_2 > 0$ and $\beta_3 = 0$; a quadratic relationship with opening upward direction, generally described as a "U-shaped curve". Researchers can obtain the turning points at $Y^* = -\frac{\beta_1}{2\beta_2}$, or $Y^* = exp(-(\beta_1/2\beta_2))$, in the logarithmic version, by setting derivatives of equation (1) equal to zero.

v. $\beta_1 \geq 0$, $\beta_2 \leq 0$ and $\beta_3 > 0$; (β_1 and β_2 cannot be zero at the same time). A cubic polynomial described as an "N-shaped" curve. This N-shaped curve is used to exhibit that EKC relationships turns or even can turn into positive direction again after a certain level of development (Phase 4 in Fig. 10). Considering about Phase 3 and 4 in Fig. 10 for advanced levels of development, and then, it might not be convincing that environmental pressure might converge to the zero levels and just disappears. Thus, the N-form relationship (or cycles in the long term) would be even more meaningful in the long term.

In (v) case, it is difficult to find the key points. According to the characteristics of a cubic equation, if an inflection point and turning points exist, researchers can obtain the turning points at:

$Y_1^{*} = \frac{-\beta_2 - \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}$ and $Y_2^{*} = \frac{-\beta_2 + \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}$ or $Y_1^{*} = exp\left(\frac{-\beta_2 - \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}\right)$ and $Y_2^{*} = exp\left(\frac{-\beta_2 + \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}\right)$, in the logarithmic version, by setting differentials of equation (1) equal to zero. Similarly, researchers can obtain the inflection point at $Y_3^{*} = -\frac{\beta_2}{3\beta_3}$ or $Y_3^{*} = exp(-(\beta_2/3\beta_3))$, in the logarithmic version, by setting quadratic differentials of equation (1) equal to zero. However, the inflection point and/or the turning points might not exist and a corresponding curve can exhibit the trend of continuous increase.

vi. $\beta_1 \leq 0, \beta_2 \geq 0$ and $\beta_3 < 0$; (β_1 and β_2 cannot be zero at the same time). A cubic polynomial generally described as an "inverted N-shaped" curve. This inverted N-shaped curve exhibits that EKC relationships turns or even can turn into negative direction again after a certain level of development. Same as (v) case, it is difficult to find the key points. According to the characteristics of a cubic equation, if an inflection point and turning points exist, researchers can obtain the turning points at

$Y_1^{*} = \frac{-\beta_2 - \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}$ and $Y_2^{*} = \frac{-\beta_2 + \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}$, or $Y_1' = exp\left(\frac{-\beta_2 - \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}\right)$ and $Y_2^{*} = exp\left(\frac{-\beta_2 + \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}\right)$, in the logarithmic version, by setting differentials of equation (1) equal to zero; the inflection point can be obtained at $Y_3^{*} = -\frac{\beta_2}{3\beta_3}$ or $Y_3^{*} = exp(-(\beta_3/3\beta_3))$, in the logarithmic version, by setting quadratic differentials of (1) equal to zero. But, the inflection point and/or the turning points might not exist and a corresponding curve can exhibit the trend of continuous decrease.

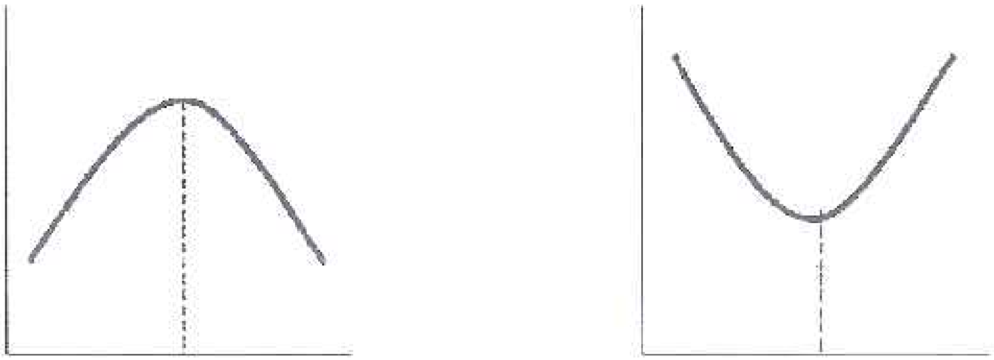
vii. $\beta_1 = \beta_2 = \beta_3 = 0$; a flat pattern or no relationship between emission and income.

If there would be an environmental Kuznets curve, calculating the inflexion point is important, which suggests the gap of economic level between current point and the inflexion point. In particular, calculating the effect of situational factors is equally important, which explains what kind of external instruments can be taken to positively influence the low emission economic development process, rather than passively waiting for the arrival of the inflexion point (Yin et al., 2015: 100).

Table 2- The Possible EKC Shapes [Source: Abid, 2015, p. 15].

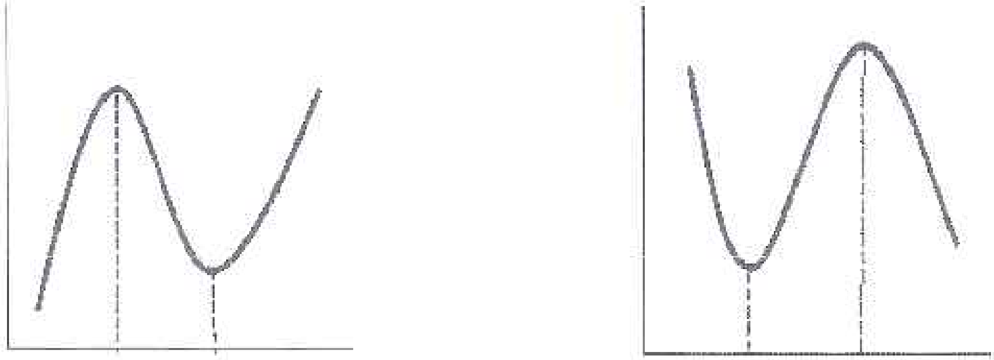
Case (i): Monotonic increasing

Case (ii): Monotonic decreasing



Case (iii): inverted U-shaped

Case (iv): U-shaped



Case (v): N-shaped

Case (vi): inverted N-shaped

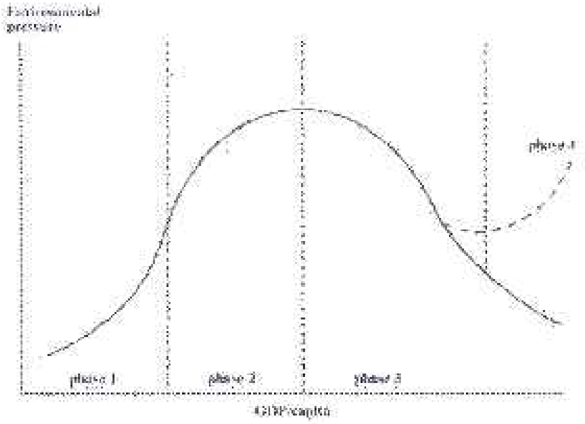


Fig. 10. Inverted U and N Relationships of Environmental Kuznets Curve [Source: Bernaciak, 2013, p. 281].

Shafik and Bandyopadhyay (1992) investigated the EKC relationship with 3 different forms as follows (Tutulmaz, 2015: 75):

$$E_{i,t} = \alpha_{i,t} + \beta_1 . \log(Y)_{i,t} + \beta_2 . \text{time} + e_{i,t} \tag{2}$$

$$E_{i,t} = \alpha_{i,t} + \beta_1 . \log(Y)_{i,t} + \beta_2 . \log(Y)^2_{i,t} + \beta_3 . \text{time} + e_{i,t} \tag{3}$$

$$E_{i,t} = \alpha_{i,t} + \beta_1 . \log(Y)_{i,t} + \beta_2 . \log(Y)^2_{i,t} + \beta_3 . \log(\mathrm{Y})^3_{i,t} + \beta_4 . \text{time} + e_{i,t} \tag{4}$$

E: environmental variable (in logarithms; in terms of per capita emissions)

Y: economic development variable (in terms of per capita income)

i, t: country and time index

α: constant term

β_{1-4}: coefficients of income, square and cubic transformations of income and time trend

time: time trend

e: error term

The level and log level data can be used in the models although the authors used logarithms of the variables in the models (2)-(4). Model (2) represents a linear relationship between per capita income (Y) representing economic development level and environmental variable (E), such as air and water emissions. By adding the quadratic income term, it becomes Model (3). It represents that the non-monotonic relationship between the income level and environmental pressure. The case of positive β_1 and negative β_2 will generate the inverted-U relationship known as EKC. By adding the cubic income term, it becomes Model (4). It represents an N-shaped relationship, is deemed as one of the EKC shapes, between the income level and environmental degradation (Tutulmaz, 2015: 75).

This shape of EKC is explained by the "*re-linking hypothesis*", indicating that the EKC may not hold even in the long run, economy can foresee upswing or cycles, which follows the inverted-U curve initially, but beyond a certain income level, the relationship between environmental pressure and income turns positive again. For instance, the levels of aggregate materials consumption over time might show an N-shape rather than an inverted U-shape curve. Such upswing of EKC can be explained with the help of the difficulty of keeping up efficiency improvements or innovation with continuing growth of production (Dinda, 2004: 446-448).

Although the reduced-form equations are intuitively sound, it is not sufficient to conclude the form of the link between per capita income and environmental degradation based on such equations. They have been criticized at least four reasons. First, they are not fitting to describe the mechanism of environmental degradation in terms of income, since they show *correlation* rather than the *causal mechanism*. Second, they assume specific functional forms *a priori* to estimate the environment-income relationship. In fact, this relationship could be more complicated than the assumed functional forms. In particular, the choice of the functional forms is more likely to affect the type and the numbers of turning points, estimates of the range of per capita income in which emissions are expected to decrease are often significantly different (Kijima et al., 2010: 1188-1190).

More specifically, a cubic function shows that environmental degradation will eventually tend to plus (or minus) infinity as income grows over time. Similarly, a quadratic (concave) function shows that environmental degradation can eventually tend to zero (or negative) at sufficiently high income levels, which is not supported by empirical evidences. Also, quadratic function (symmetric) implies that the uphill portion of the curve has the same slope as the downhill part. This suggests that, when income goes beyond some threshold level, environmental degradation will decrease at the same rate as it previously increased, which is very unlikely; this is because many forms of environmental degradation can be extremely difficult to decouple. In general, most pollutants tend to accumulate and persist for a long time, so that they are often much harder to mitigate than to produce (Kijima et al., 2010: 1190).

All in all, based on theoretical research, for the complex bi-directional link between environmental quality and economic-social development, researchers have begun to investigate more sophisticated econometric techniques of estimation and of curve fitted function (Kijima et al., 2010: 1190). In this regard, researchers have refined the empirical strategies. For instance, estimation methods have varied from OLS estimation, panel data estimations with fixed or random effects, generalized method of moments, Tobit estimations, and semi parametric estimations. In addition, explanatory variables have been augmented including lagged values, population density, locational variables, micro or macro variables, distributional variables, trade variables, and non-economic variables (literacy rates, inequality, civil liberties and political rights, etc.). In particular, these efforts have only found wide variations across nations considering the income-environmental relationship depending on the emissions, and consequently this relationship seems to be less robust than previously thought. More recently, new empirical studies have been developed using state-of-the-art panel cointegration techniques and individual time series (Esteve & Tamarit, 2012a: 2697).

CHAPTER 2

LITERATURE AND THEORETICAL CONSIDERATIONS

The standard theoretical and analytical framework for the investigation of global warming and air pollution in the literature is the prominent theory of the Environmental Kuznets Curve (EKC). This theory is built to explain how shifts of the economic structure, income-induced policy changes, demographic changes as well as political and economic institutions form an inverted U-shaped relationship between economic growth and global warming and also air pollution. The dynamic GMM model this thesis designs is based on this theoretical framework in such a way that the selection of causal and indicator variables is based on the insights of the literature on the EKC.

Previous studies have used an enormous range of variables as determinants of pollution. Indeed, as most studies do not satisfactorily control for different measures of pollution, samples and sets of conditioning variables, it remains questionable whether the suggested explanatory variables are *robustly* linked to the level of environmental quality (Lamla, 2009: 135). These studies provide the cornerstones of this thesis. From a theoretical point of view, combination of the studies guides this thesis about the existence of economic growth/development and environmental degradation link through the two main factors including economic and governance. For the purposes of this thesis, which is to empirically test hypotheses derived from the existing theories on the presence of EKC, a measure of pollutant should fulfill the following requirements suggested by Bernauer and Koubi (2009): first, be produced by human acrivity; second, be subject to regulations, if governments wish to, due to its harmful effects of humans, ecosystems and the economy; third, have available abatement technologies for implementation of the regulations; fourth, for statistical purposes, have data available from a mix of developed and developing nations.

2.1. Literature on Environmental Indicators

2.1.1. Indicators

Environmental pollution is a significant issue in the process of economic growth (Hitam & Borhan, 2012: 333). It refers to any discharge of material or energy into water, land, or air that causes or might cause acute (short-term) or chronic (long-term) detriment to the Earth's ecological balance or that lowers the quality of life and that threats to the survival of humanity (Gheorghe & Ion, 2011: 242). It occurs when the environment can no longer deal with the unsafe by-products of human activities. It results when the natural environment is incapable of decomposing unnaturally produced elements while on the other hand humans lack the know-how on dealing with these pollutants artificially (Hitam & Borhan, 2012: 333-334), including vehicle emissions, agricultural runoff, accidental chemical release from factories, poorly-managed harvesting of natural resources, etc. In some cases, pollution might be reversible with costly environmental remediation measures, but in other instances, it might be irreversible or take decades or even centuries for the environment to cope with the pollution (Hassan et al., 2015: 58).

Environmental pollution, in its many forms, could be threefold 'whammy'; it affects the environmental processes which provide natural and industrial resources, a person's quality of life and the process of economic development (Bouvier, 2014: 40). Considering the first one, environment is very indispensable in every aspect of life. That is to say, all the process of entities is performed under the environment, including all the living beings are influenced by the environment; all the components required for survival of living organisms are gained through environment containing air, water, soil, food, clean environment; the development of living creatures i.e., quality of human life, sector developmental activities, growth, natural resources for development of civilization of human beings, plant and animals are depend upon the environment (Hassan et al., 2015: 67).

Considering the second one, any form of pollution is directly related to a person's quality of life. On one hand, the effects of pollution may be self-evident, as in the polluting of drinking water (causing typhoid, amoebiasis, giardiasis, ascariasis, hook warm), or exposure to polluted sea waters (causing skin ailments, respiratory infection, intestinal problems, hepatitis, auditory and visual problems), or the visible smog (affecting the lungs, eyes, nose, mouth and throat, causing asthma attacks and related side effects such as plummeting energy levels, cancer, premature death); on the other hand, may be more subtle that affect our well-being in ways of which we are unaware. For instance, we are only just beginning to tease out the links between gene expression and certain pollutants. Moreover, the level and type of pollution a person is exposed to can affect that person's ability to function both in the economic sphere ('black lung,' having prematurely shortened the working lives of many miners in Appalachia and around the world) and in the leisure sphere (asthma affecting a person's ability to participate in sports) (Bouvier, 2014: 39-40).

Considering the third one, pollution substantially affects the individuals and society's productive potential, the process of economic development (human and natural resources and building up of capital and technology), as well as the level of economic development of a nation, where economic development means the rising standards of living associated with sustained economic growth from existing levels to a better, modern and high-income economy (Hitam & Borhan, 2012: 334). There are a number of studies that investigate the link between environmental degradation and economic growth/development. According to Meadows et al. (1992), far from being a threat to the environment in the long-term, economic growth seems to be necessary to maintain and improve the environmental quality. Also, Anderson (1992) suggested that the tradeoff between economic growth and environmental quality is not invariant to policies. This issue is particularly important for the transitional nations, which aim to achieve higher rates of economic growth face the danger of adopting economic policies that run contrary to their long-term environmental sustainability objectives (Tamazian & Rao, 2010: 138).

Some researchers argued that the net effect of economic growth/development on environmental quality depend upon the characteristics of different pollutants. For instance, some air pollutants like suspended particulate matter, sulfur dioxides, carbon monoxide and oxides of nitrogen, which have relatively significant health and environmental degradation effects, appear to take an inverted U-shaped relationship with economic development. Also, Selden and Song (1994) found similar results for various air pollutants like SO_2, NO_x and CO. However, Shafik and Bandyopadhyay (1992) argued that the CO_2 emissions have been found to increase monotonically with per capita GDP. Goldemberg (1998) stated that environment disasters might be prevented by following the past steps by the industrialized nations. The industrialized have incorporated modern as well as efficient technologies early in the development process. Nevertheless, Panayotou (1997) found that the quality of both policies and institutions in a nation could significantly reduce environmental degradation even if a nation's income level is low. Higher future income levels are likely to speed up improvements to the environment. Policies like more secure property rights under the rule of law and better enforcement of contracts as well as effective environmental regulations could help flatten the EKC and reduce the environmental cost of higher economic growth (Tamazian & Rao, 2010: 138).

The upcoming section discusses and motivates the environmental quality indicators employed in this thesis. An *environmental quality indicator* is defined as "a number indicating the state and development of the environment or conditions affecting the environment" (Alfsen & SÆBØ, 1993, p. 416). It is used to evaluate the environment's capacity for supporting human and ecological health and to gauge progress in meeting short- and long-term environmental goals. It could warn of impending environmental issues and enhance policymakers' and regulators' ability to manage as well as resolve these issues (Michigan Nonprofit Association Council of Michigan Foundations, 1998).

There exist many pollutants that could serve as indicators of environmental quality. Obviously, it would be considered two main measures of global warming and local air pollution as indicators of the environmental quality, the first one being an:

2.1.1.1. *Indicator of Global Warming*

Global warming is the most discussed and feared environmental concern in the world today in regards to climate change. Global average temperature has already increased by 0.6 °C and could increase to 6.4 °C by 2100 (Miah et al. 2010: 4643). Fig. 11 illustrates global temperature variation. This trend of increasing temperatures throughout the world has continued up to the present in "a global demonstration of the Tragedy of the Commons" and 'the biggest market failure the world has seen'. There are several reasons for global warming. According to the latest report from the Intergovernmental Panel on Climate Change (IPCC), with 95% certainty, humans are the principal drivers of the rapid global warming we have experienced over the period since the beginning of the industrial revolution, and that the culprits are the greenhouse gases that we have been emitting (Long & Tyson, 2014: 326).

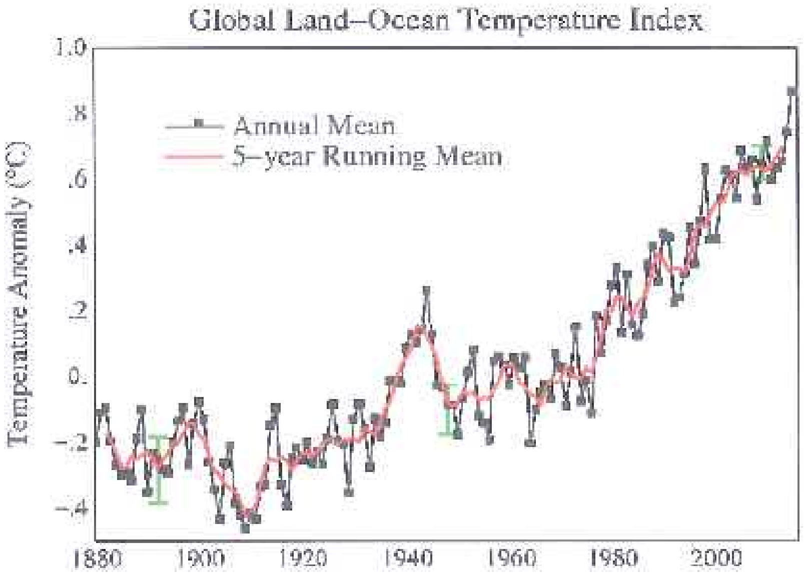


Fig. 11. Global Temperature Variation [Source: NASA satellite data].

The most significant greenhouse gases (GHGs) are carbon dioxide (CO_2), sulfur oxides (SO_x), nitrogen oxides (NO_x), methane (CH_4) and F-gases (gases that contain Fluorine). Moreover, the contribution of suspended particulate matter (SPM), waste emission (for emission of CH_4) and deforestation cannot be ignored. Among them, CO_2 is considered as the major GHG that contributes the "lion's share in global warming" (Miah et al., 2010: 4643-4646). Fig. 12 illustrates CO_2 (ppm) trend over years. According to an IPCC report, CO_2 emitted from fossil fuel combustion and industrial process contributes about 78% of the total GHG (IPCC, 2014: 5). The three types of fossil fuels that are used the most are coal, natural gas and petroleum (oil). When fossil fuels are combusted, the carbon stored in them is emitted almost entirely as CO_2 (Hassan et al., 2015: 58). Hence, it is utilized the log of CO_2 emissions per capita from the World Bank as the main indicator of global warming. According to the World Bank's definition, emissions of CO_2 stem from the burning of fossil fuels and the manufacturing of cement. Estimates of CO_2 also include CO_2 produced during production processes through the consumption of solid, liquid, gas fuels, and flaring.

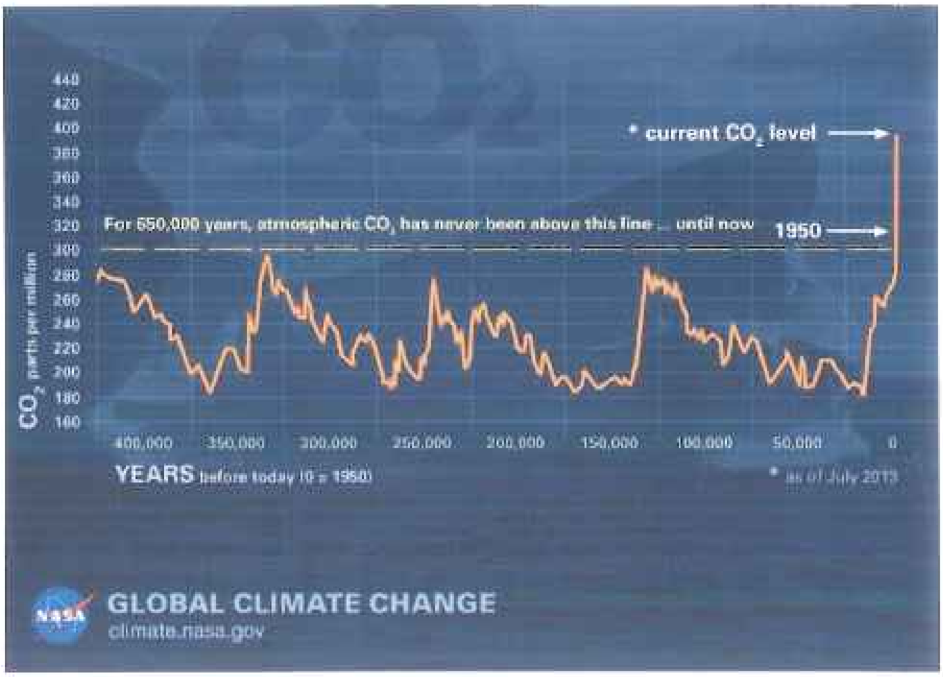


Fig. 12. CO_2 (ppm) trend over years [Source: NASA satellite data].

Global warming in particular carbon dioxide (CO_2) emissions fulfills the abovementioned requirements. A first requirement, global warming has been widely considered as one of the most significant environmental indicators. Moreover, CO_2 is perhaps the most prominent form of greenhouse gas worldwide, and used by the World Bank, the IPCC, the Kyoto Protocol, as well as numerous other national and international authorities to investigate and to report global warming at least two reasons. The former, increases in the emission of this gas give a direct correlation to global warming (Miah et al., 2010: 4646). For instance, over half of the predicted global warming impacts are expected to result from CO_2 (Kazemi et al., 2013: 3356). This is why the study of EKC for CO_2 is very significant (Miah et al., 2010: 4646). The latter, the primary source of this CO_2 is fossil-fuel combustion, an activity that state and local officials address by regulating categories of emission sources (Kazemi et al., 2013: 3356).

A second requirement, CO_2 emissions are part of a collection of gases that negatively affect the quality of air and raise the greenhouse effect. Greenhouse gases have a direct impact on the environment, including causing extreme weather events (heat waves, droughts, thunderstorms and flooding), a global temperature increase (melted glaciers and ice caps, increasing sea levels), the loss of ecosystems and potentially hazardous health effects for people. It is clear that the CO_2 is adversely affecting the environment which is against the sustainable objectives (Hassan et al., 2015: 67). According to the World Economic Forum's Global Risks 2016 report, a global economic crisis would most likely occur as a result of extreme weather events. Also, Stern (2007) estimated that economic loss from 2007 to 2020 would be 13.8% of global GDP due to global warming. This is significantly higher than the loss during World War I (4.98%) and World War II (6.97%) (Tsai et al., 2016: 416).

A third requirement, CO_2 emissions can be controlled, if governments wish to, by altering the techniques of production. While some carbon dioxide is also emitted by natural sources, it is primarily produced from the burning of fossil fuels that are the major artificial greenhouse gas in the atmosphere (Tsai et al., 2016: 416). It is clear that we establish at this point that we humans can no longer be considered 'separate' from the natural systems we inhabit, at least when it comes to climate change. Since humans are leading to the climate problems, humans also hold the key to solving it (Long & Tyson, 2014: 326).

Empirical evidence has shown that technological progress is the key factor for constraining and reducing CO_2 emissions. Particularly, energy intensity acting as drivers of CO_2 emissions (i.e. the improvement of energy mix and energy efficiency) must receive specific attention. It is a direct method for reducing energy intensity to improve the energy efficiency and substitute energy for other input factors in the industry. In addition, the arrival of new upgraded or improved technologies as well as innovation could stimulate the energy efficiency of production process in energy-intensive industries (Yuan & Zhao, 2016: 108).

According to Stern (2007), effective policies against global warming should take into consideration the following forms: technological policies to increase energy efficiency, applications of low-carbon and energy-saving products, and imposition of carbon taxes. In addition, according to the special report 'CO_2 Capture and Storage' in IPCC (2005), three technologies that might mitigate greenhouse gases focus on increasing energy efficiency, adopting renewable or clean energies, and retrieving or storing CO_2 (Tsai et al., 2016: 416-417). Yuan & Zhao (2016) concluded that a series of effective stimulating measures of green technological innovation and adoption, including the improvement of energy utilization efficiency, production according to ecological principles, and innovations in energy production (i.e. a transition the energy mix from traditional fossil fuels to renewable and alternative energy) should be taken into the policy portfolio as soon as possible across worldwide nations.

A fourth requirement, availability of data that is commensurable for a large number of nations and over long time periods is a major problem in this type of research. Data for CO_2 emissions is more reliable than data for other forms of global warming, and it is also available for a rather large number of nations since 1959. Data with similar properties is not available for most other greenhouse gases (GHGs), for instance, sulfur oxides (SO_x), nitrogen oxides (NO_x), methane (CH_4) and F-gases (gases that contain Fluorine). In addition, it is not employed composite environmental quality indices, such as the Environmental Performance Index (EPI) and Environmental Sustainability Index (ESI), have been built in the last decade.

The 2016 version of the EPI measures the environmental performance of a nation according to nine policy categories: health impacts, air quality, water and sanitation, water resources, agriculture, forests, fisheries, biodiversity and habitat, and climate and energy. The nations` performance in these nine categories is then summarized in two broad categories: environmental health and ecosystem vitality. Both categories received an equal weight of 50% in previous versions of the EPI. The finally calculated EPI ranges from 0 to 100, higher values indicating greater success in meeting environmental targets (Hsu et al., 2016).

The Environmental Sustainability Index (ESI) refers to a measure of overall progress towards environmental sustainability. The index gives a composite profile of national environmental stewardship based on a compilation of indicators derived from underlying datasets. The ESI is the predecessor of the EPI, available for the years 2000, 2001, 2002, and 2005. Also, the ESI developers employed twenty-one indicators (air quality, biodiversity, land, water quality, water quantity, reducing air pollution, reducing ecosystem stress, reducing population pressures, reducing waste and consumption pressures, reducing water stress, natural resource management, environmental health, basic human sustenance, reducing environment-related natural disaster vulnerability, environmental governance, eco-efficiency, private sector responsiveness, science and technology, participation in international collaborative efforts, greenhouse gas emissions, reducing transboundary environmental pressures) in order to build this index (Esty et al., 2005).

These indicators permit comparison across a range of issues that fall into the following five broad categories, for instance environmental systems, reducing environmental stress, reducing human vulnerability to environmental stress, societal and institutional capacity to respond to environmental challenges, as well as global stewardship. Each of the twenty-one indicators received an equal weight. The higher a nation's ESI score, the better positioned it is to maintain favorable environmental conditions into the future (Esty et al., 2005).

Despite its success and popularity, both the EPI and ESI have been criticized due to measurement problems. Although estimates for the EPI are available for the years 2000-2016, changes in, for instance, data sources, the weighting of categories as well as the aggregation method make it difficult to compare the EPI for different years. The developers of the EPI also acknowledge this problem and emphasize that researchers cannot use the EPI in panel data (or time series) analysis as the scores are not comparable over time. The main reasons they mention are changes in '*data sources, imputations, methodology, framework, target setting, weighting, and aggregation*'. Consequently, the same critique as for the EPI applies to the ESI: the ESI scores or rankings should not be compared to earlier versions because of changes to the methodology and underlying data (Buehn & Farzanegan, 2013: 105).

Both indices have been used in the literature, mostly in cross-country studies, to investigate the effect of social and institutional factors on environmental quality. Due to equal weighting procedure of the ESI, Jha and Murthy (2003) were concerned about the fact that the existing literature did not try to link any of the environmental composite indices to economic development and it ignored two main problems: the first could be addressed by computing a more comprehensive aggregate measure of environmental degradation, of which pollutants would only be a subset. That is, linking individual pollutants to the level of per capita income provides an incomplete picture because many pollutants are related to each other and to other indicators of environmental degradation. In addition, a nation's per capita income might be only an imperfect indicator of its development.

The second could be addressed by relating this measure to a more complete measure of economic development, particularly, the human development index (HDI). Thus, they applied principal components analysis (PCA) combining different indicators, to build a composite index of environmental degradation (EDI). Using their index in a cross-country study, they investigated the relationship to the HDI and introduce the concept of a 'global environmental Kuznets curve (GEKC)' (Buehn & Farzanegan, 2013: 105).

Apart from the ESI and EPI, some studies use the Ecological Footprint (EF) index, as a broader proxy of environmental performance. The EF index 'measures the human demand on nature by assessing how much biologically productive land and sea area is necessary to maintain a given consumption pattern' (Buehn & Farzanegan, 2013: 105). This can be compared to available biocapacity, expressed in land and sea areas. If global demand on area exceeds global supply of biologically productive area, this reflects an overshoot, which is core concern for sustainability (Wiedman et al., 2006: 29)

The EF has been used by a growing number of government authorities, agencies, organizations and communities as a metric of ecological performance. Despite its success and popularity, the EF has been criticized for, not accurately representing the impacts of consumption, not correctly allocating responsibilities, not being useful for policy makers (Wiedman et al., 2006: 29), as well as measurement problems like the ESI and EPI, i.e., they are available only for very few (even most recent) years and usually combine ecological and environmental policy components whereas this thesis seeks to study the effects of political variables on ecological outcomes.

2.1.1.2. *Indicator of Air Pollution*

Air pollution is a major environmental issue and it comes in a variety of forms, from visible particles of soot or smoke to invisible gases particularly sulfur dioxide and carbon monoxide, and it can be created indoors and outdoors. While some sources of air pollution are emitted naturally from volcanoes and forest fires, most are the result of anthropogenic activities (Agnoletti & Neri Serneri, 2014: 143-144). The major anthropogenic sources of air pollution fall into the four main categories: first, industry and conventional energies (the mining industry, the energy industry based on fossil fuels, notably coal, oil, natural gas, central heating, chemical and metallurgical industry, and engineering internal combustion machinery industry, industrial waste, noises, etc.); second, agriculture (the vegetation fire, denitrification in soils excessively fertilized, paddy field, intensive husbandry, deforestation, etc.; third, transportation (motor vehicle pollution, noises, etc.); and fourth, urbanization (sewage plans, authorized landfill site, etc) (see Fig. 13) (Gheorghe & Ion, 2011: 244-245).

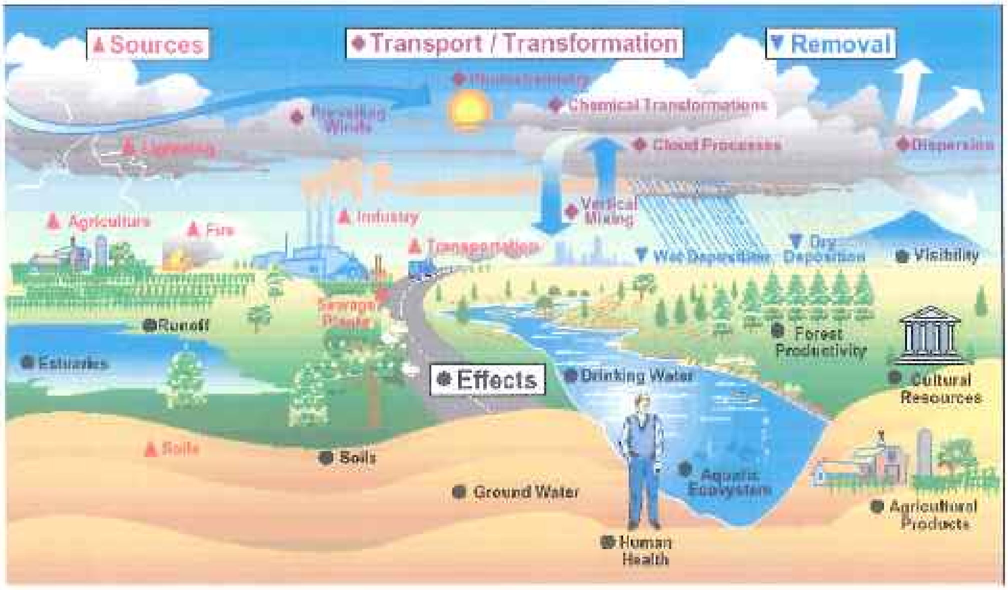


Fig. 13. Global Pollutants Circuit [Source: Gheorghe & Ion, 2011, p. 242].

The main air pollutants are sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxide (NO_2), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$) and lead (Pb). However, among them, SO_2 in the ambient air becomes a pollutant of environmental significance. Like most pollutants, SO_2 has both natural and anthropogenic sources. Natural sources include volcanic eruptions, sea-salt emissions, and oxidation of other sulfur gases, while anthropogenic sources include burning coal, biomass combustion, and industrial combustion. Emissions of SO_2 from the latter produce predominantly as fossil fuel combustion at power plants (73%) and other industrial facilities (20%) (Ray & Kim, 2014: 101). As a result, it is used the log of SO_2 emissions per capita the as the main indicator of air pollution. The data set is developed by Smith et al. (2011) who provide annual estimates for the global and regional anthropogenic sulfur dioxide emissions from 1850 to 2005 (see Fig. 14). The final SO_2 emission estimates represent the sum of SO_2 emissions from a variety of sources: coal, petroleum and biomass combustion, natural gas processing and combustion, petroleum processing, shipping bunker fuels, metal smelting, pulp and paper processing, other industrial processes, agricultural waste burning.

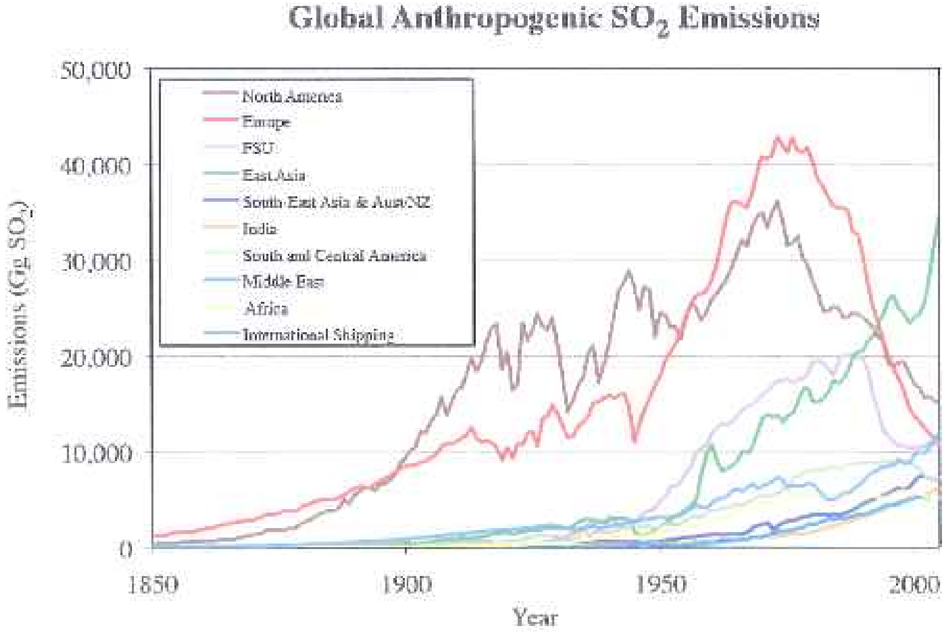


Fig. 14. Global Sulfur Dioxide Emissions by Region [Source: Smith et al., 2011, p. 1110].

Air pollution in particular emissions of sulfur dioxide (SO_2) fulfills the abovementioned requirements. A first requirement, air quality is widely regarded as one of the most significant environmental indicators (Bernauer & Koubi, 2009: 1358). Also, SO_2 is one of the most preferred pollutants by the World Bank, the OECD, as well as numerous other national and international authorities to investigate and to report air quality at least two reasons (Bernauer & Koubi, 2009: 1358). The former, sulfur emissions have been one variable for which there is evidence that there is an inverted U-shape EKC. Therefore, it is of main interest of researchers to examine this variable in a study of the possible downward bias of existing estimates. In addition, simultaneity issues might be less important than they might be for other variables (CO_2 and deforestation). Moreover, sulfur could be removed using 'end of pipe' technologies and substitution away from coal or high-sulfur coal is far easier than substitution away from fossil fuels in general. Furthermore, changes in sulfur emissions are less likely to drive GDP growth than are changes in other variables (energy use and CO_2) (Stern & Common, 2001: 163-164). The latter, SO_2 is one of the so-called "criteria" air pollutants (i.e., carbon monoxide, nitrogen oxide, ozone, particulate matter and lead) for which there are federal air quality standards to protect public health and welfare.

A second requirement, SO_2 is the most prominent form of air pollution worldwide, since it has direct and visible effects on human health, ecosystems, and the economy (Bernauer & Koubi, 2009:1358). Emissions of SO_2 to the atmosphere have become one of the main concerns at a variety of spatial scales. For instance, the health of households is threatened wherever coal is burned in the home for domestic cooking and heating, urban populations are at risk in those cities where fossil fuels are used for power generation and industrial manufacturing, ecosystems at national and continental scale are threatened by the deposition of acidic sulfate, and the global climate is influenced by the buildup of sulfate aerosol (Streets et al., 2000: 4413).

A third requirement, SO_2 has a unique characteristic, which can be controlled, if governments intend to, through changing the techniques of production, tougher environmental policy and regulation. While some sulfur dioxide is emitted by natural sources, such as volcanoes and decaying organic matter, it is primarily produced from anthropogenic activities, such as industrial production and fuel combustion, notably oil and coal (Bernauer & Koubi, 2009:1358). It implies that the SO_2 emission inventory can be seen as a proxy of economic growth, that is, the emission efficiency of SO_2 may depend on the economic stage of development (Kawamoto et al., 2004: 354). For example, in industrialized nations SO_2 is produced mainly from electricity generation and the smelting of non-ferrous ores, but in the case of developing nations it is primarily emitted from the burning of diesel fuel and home heating. Statistical evidence has shown that SO_2 emissions could be curtailed by reducing consumption of fossil fuels (particularly high-sulfur coal), by the installation of better *end of pipe* (EOP) abatement technology including the use of smoke-scrubbing equipment in power plants and smokestacks, by reducing the sulfur content of fossil fuel and by rising energy efficiency (Bernauer & Koubi, 2009: 1358).

Although a variety of emission reduction measures are readily available and effective (Bernauer & Koubi, 2009: 1358), there is a cost associated with the SO_2 abatement effort, and the cost structure varies across firms and industries (Li et al., 2015: 453). For instance, in 1990, the U.S. Environmental Protection Agency (EPA) estimated the cost of implementing the Acid Rain Program at $6.1 billion; in 1998, the Electric Power Research Institute (EPRI), which is an industry organization, and Resources for the Future (RFF), which is an independent think tank, estimated that total implementation costs would be $1.7 and $1.1 billion respectively (Chan et al., 2012: 5-7). However, marginal abatement costs for SO_2 are much lower today than were estimated in the 1990s. The typical unit's marginal abatement cost function is lowered by almost $50 dollars per ton of SO_2 due to technical improvements such as advances in the ability to burn low-sulfur coal at existing generators, as well as improvements in overall generating efficiency. In addition, the decline in fuel costs lowered marginal abatement costs by about $200 per ton (Carlson, Burtraw, Cropper & Palmer, 2000: 1293-1294).

The benefits of curbing SO_2 embody the avoided health and environmental damages of SO_2 emissions (Wang & Corbett, 2007: 582). For instance, Chen et al. (2002) showed significant health benefits between $540 and $887 million per year from energy efficiency improvements and the expanded use of natural gas to replace coal consumption in the city (Li et al., 2004: 50). Burtraw and Toman (1998) found that reductions in premature mortality alone typically account for 75 to 85 percent of economic estimates of the benefits of improved air quality. Reduced morbidity accounts for a much smaller fraction despite being significant. For example, both Burtraw et al. (1998) and USEPA (1996) found that reduced morbidity accounted for roughly 5 percent of the benefit from reducing sulfur dioxide emissions (Williams III, 2003: 325). Moreover, Wang and Corbett (2007) found that net benefits of curbing SO_2 emissions from cargo ships in the US West Coast waters range between $98 million and S284 million, annually; the benefit-cost ratio varies between 1.8 and 3.36, depending on the size of the control area and the sulfur content limit.

A fourth requirement, availability of data that is commensurable for a large number of nations and over long time periods is a major problem in this type of research. Data for SO_2 emissions is more reliable than data for other forms of air pollutants, and it is also available for a rather large number of nations since 1850. The same criteria as for CO_2 applies to SO_2 as well: Data with similar properties is not available for most other air pollutants, for instance, carbon monoxide (CO), nitrogen oxide (NO_2), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$), and lead (Pb). In addition, it is not employed composite environmental quality indices, such as the Environmental Performance Index (EPI) and Environmental Sustainability Index (ESI) as well as the various indices for anthropogenic Ecological Footprint (EF) in this thesis, since they are available only for very few (most recent) years and usually combine ecological and environmental policy components whereas this thesis seeks to study the effects of political variables on ecological outcomes.

2.2. Theoretical Considerations

For clarity, the causes of environmental degradation are grouped into two main categories: economic and governance factors.

2.2.1. Economic Factors

One of the most robust determinants of both global warming and air pollution is economic development measured by real per capita GDP based on purchasing power parity (PPP). A central argument is that greater economic development might hurt the natural environment, but this relationship is just partly true. Adapted from Kuznets' (1955) original study on the impacts of economic development on income inequality, the Environmental Kuznets Curve (EKC) hypothesis postulates that environmental quality first declines (traditionally measured by *arise* in pollution) in response to economic development, and improves (pollution levels *fall*) only after per capita income surpasses a critical threshold. This combination of falling then rising environmental quality (as measured by pollution output) produces an inverted 'U' shaped curve during the course of economic growth and resulting development (Caviglia-Harris et al., 2009: 1149-1150).

From the theoretical point of view, several logics have been formulated in order to explain the EKC hypothesis: (i) it can be that the pattern reflects the natural progression of economic development, from clean agrarian economies to polluting industrial economies and finally to clean service economies; (ii) pollution involves externalities and appropriately internalizing those externalities requires relatively advanced institutions for collective decision-making that may only be implementable in developed economies; (iii) threshold effects: at low levels of economic activity, pollution may be unregulated entirely or regulation may have little impact on the profitability of abatement (pollution increases with income); but after some threshold has been reached, policy starts to bind (pollution declines with income); (iv) there exist increasing returns to abatement (Fernández et al., 2012: 1700).

Research on the validity, application, and measurement of the Environmental Kuznets Curve (EKC) has been prolific. If the Environmental Kuznets Curve (EKC) is valid and "panacea" for all types of environmental degradation, then sufficient economic development alone will solve environmental issues in both developed and underdeveloped nations (Caviglia-Harris et al., 2009: 1149). Thus, a large number of econometric studies have been made to test the emergence of the EKC in a wide variety of income-based environmental degradation. Typically, most of such studies found three possible scenarios (see Fig. 15) (Buehn & Farzanegan, 2013: 106):

- *Monotonically decreasing*: the economy is in situation A if the estimated coefficient of real GDP per capita is negative and statistically significant while the coefficient of the squared term is not;
- *Inverted-U*: the economy is in situation B if the coefficient of real GDP per capita is positive and statistically significant and real GDP per capita squared is significantly negative;
- *Monotonically increasing*: the economy is in situation C if the coefficient of real GDP per capita is positive and statistically significant, and also the coefficient of the squared term is insignificant.

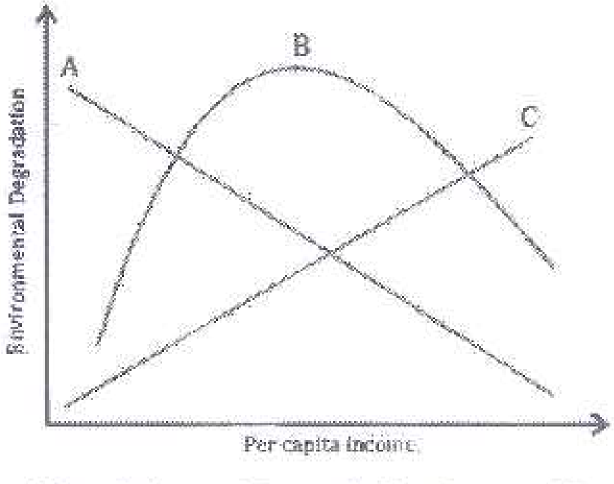


Fig. 15. Environmental Degradation and Economic Development [Source: Buehn & Farzanegan, 2013, p. 106].

On the other hand, a number of recent theoretical and empirical studies with respect to the link between economic development and emissions have provided conflicting results, depending on the analysis used (cross-country or time series) and on the period under examination (Table A1 and Table A2 in Appendix summarizing some EKC-studies that deal with both CO_2 and SO_2 emissions, respectively). They have argued that the inverted U-shaped EKC is not the most convincing model, given that the slope or form of the curve might take various shapes according to the type of pollutant as well as context of pollution. For instance, De Bruyn and Opschoor (1997) introduced the N-shaped scenario, in which economic growth generates environmental amelioration initially, but beyond a certain income level, it leads to more severe air pollution (Park & Lee, 2011: 5843).

Besides the conventional EKC and the N-shaped scenarios, Dasgupta et al. (2002) introduced three more scenarios: first, the worst-case scenario, in which the incessant increase in pollution does not enable environmental improvement; second, the 'race to the bottom' scenario, in which advanced nations continue to implement environmental regulations in ways that are advantageous to themselves; and thirdly, the revised scenario of conventional EKC, in which citizens' consciousness and awareness as well as behavior become eco-friendly exists from the beginning of industrialization, creating environmental improvement. These different scenarios are illustrated in Fig. 16. (Park & Lee, 2011: 5843).

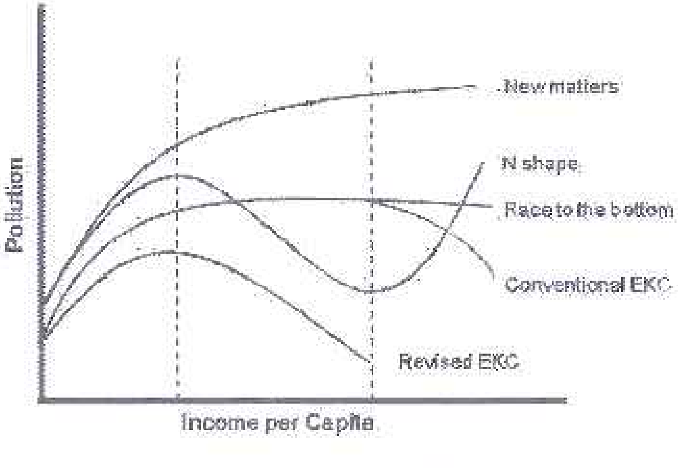


Fig. 16. Various EKC Scenarios [Source: Park & Lee, 2011, p. 5843].

Based on the scenarios explained above, Hypothesis 1 and 2 of this thesis investigate what kind of relationship exists between global warming and air pollution caused by CO_2, SO_2 and economic growth. To test these hypotheses, it is included the level, squared as well as cubic transformations of (the log of) real GDP per capita (LGDPPCPPP, $LGDPPC^2PPP^2$, $LGDPPC^3PPP^3$). This is because testing the EKC hypothesis requires including the real GDP per capita, its squared term and its cubic term in the empirical specification.

The variable $LGDPPC^2PPP^2$ refers to the case of a national economy that follows an inverted U-shape pattern. If the coefficient of real GDP per capita is positive and statistically significant and real GDP per capita squared is significantly negative, the inverted U-shape is verified. While the variable $LGDPPC^3PPP^3$ refers to the case of a national economy that follows an N-shape pattern. If the coefficient of real GDP per capita is positive and statistically significant and real GDP per capita squared is significantly negative as well as real GDP per capita cubic is significantly positive, the N-shape is verified. The source of real per capita GDP data is the World Bank (2015).

Hypothesis 1: Emissions of CO_2 and SO_2 will have a statistically significant relationship with real per capita GDP, showing an inverted U-shaped curve, ceteris paribus.

Hypothesis 2: Further, emissions of CO_2 and SO_2 will have a statistically significant relationship with real per capita GDP, showing an N-shaped curve, ceteris paribus.

In order to mitigate the omitted variables biases in the earlier EKC studies, subsequent studies on the environment-growth/development nexus have incorporated other factors (other than per-capita income) that may influence environmental quality (Li et al., 2016: 139).

A commonly expressed view is that the structure of the economy might help explain the level of emissions and air quality (Buehn & Farzanegan, 2013: 106). Manufacturing and industrial processes all combine to produce large amounts of CO_2 and SO_2 at least two reasons: the former, many manufacturing facilities directly use fossil fuels to create heat and steam which is needed at various stages of production. The latter, their energy intensive activities use more electricity than any other sector so unless they are using renewable sources the energy that they use is responsible for excessive amounts of emissions as well. Industrial production means manufacturing, construction, mining, and agriculture. Manufacturing is the largest of the four and can be divided into five main categories, i.e., paper, food, petroleum refineries, chemicals, and metal/mineral products. All in all, these categories account for the vast majority of the energy use and emissions by the sector (Hassan et al., 2015: 58). These arguments set up the third testable hypothesis. To test the environmental implications of the structure of the economy, it is used the industry's value added to GDP (INDUS). The source of the industry's value added to GDP data is the World Bank (2015).

Hypothesis 3: A higher share of the industrial sector to GDP increases global warming and air pollution, ceteris paribus.

Besides the degree of industrialization, the composition of a nation's electrical power supply might play an important role in the quality of environment (Buehn & Farzanegan, 2013: 107). This may be seen as a double-edged weapon: On one hand, nations try to create order in the economic system; on the other hand, they create unintentionally disorder in the nature, although this disorder can be in the sun or space rather than on Earth (Mudakkar et al., 2013: 581). For instance, as nations develop and advance, they typically experience a significant expansion in their production and consumption of electricity due to vital role of electricity in modern economic activity (Burke, 2010: 616). Thus, a higher share of electricity produced from coal sources would on average increase emissions (Buehn & Farzanegan, 2013: 107).

Sustained rising per capita income of the sort associated with economic development, however, enables several environmental strategies and policies which underscore the necessity for a clean and efficient energy supply. These policies aim to transform the current energy system into a sustainable and low-carbon system, which will take into consideration far-reaching implications on how to produce energy. Due to the raised environmental awareness and consciousness as well as eco-friendly behavior of the role played by energy in our society, it is imperative to find effective ways for assessing the environmental effect of the technologies available for electricity generation in order to move towards an environmentally friendly electricity mix (i.e., eco-friendly mix) (Ewertowska et al. 2016: 13).

Electricity supply mix, is the bundle of sources used in generating electricity, has recently received increasing public attention for not only the role it plays in environmental quality but also in sustainability. Nuclear and renewable energy sources have become promising alternatives to reduce the dependence on fossil fuels in the last decade (Ewertowska et al. 2016: 13). They should be promoted in every stage of economic development at least four facts. The first, they have much less environmental impact compared to other sources of energy since there is no any energy sources with zero environmental impact. The second, there are a variety of choices available in practice that a shift to renewable sources could provide a far cleaner energy system than would be feasible by tightening controls on conventional energy. The third, they cannot be depleted unlike fossil fuel and uranium resources. As long as they are used wisely in appropriate and efficient applications, they can provide reliable and sustainable supply energy almost indefinitely. The fourth, they favor power system decentralization and locally applicable solutions more or less independent of the national network, and thereby enhancing the flexibility of the system and the economic power supply to small isolated settlements (Dincer, 2000: 172-174).

Based on the theories explained above, hypothesis 4 of this thesis investigates what kind of relationship exists between global warming and air pollution caused by electricity supply from different sources (coal and nuclear and alternative energy sources). To test this hypothesis, in line with Buehn and Farzanegan (2013), it is utilized the share of electricity production from coal sources (hard and lignite-brown coal and derived fuels like patent fuel, coke oven coke, gas coke, coke oven gas, and blast furnace gas) in total electricity production (COAL_ENERGY) and the share of alternative and nuclear energy sources (hydropower, geothermal, solar power, among others) with respect to total energy use (ALTERNATIVE_ENERGY). The source of both data is the World Bank (2015).

Hypothesis 4: A high share of electricity supply from coal sources leads to more emissions, while a high share of electricity supply from alternative energy sources leads to less emission, ceteris paribus.

When regarding the attributes of the underlying industry a proxy of efficiency is of great importance. The World Bank measures energy efficiency by the GDP per unit of energy use (GDP/energy use). Accounting for other characteristics of an economy, this intends to proxy for the level of efficiency in the production process. It is assumed that nations should be able to achieve this conditioning in a sufficient way through implementing economic and political factors. It is primarily a technical and historical process caused by stock turnover where old equipment is replaced by new upgraded more efficient ones. It is indeed a by-product of some social objectives like productivity, comfort, monetary savings, fuel competition (Herring, 2006: 11). Increasing energy efficiency allows using energy more economically, which in turn decreases emissions, all other things being equal. Therefore, it can be took energy efficiency as a conditional variable to discover the influence on the shape of both the CO_2 and SO_2 Kuznets curve. On the basis, Hypothesis H5 is proposed:

Hypothesis 5: Energy efficiency changes the shape of the EKC: a higher level of energy efficiency flattens the decreasing portion of the curve, ceteris paribus.

2.2.2. Governance Factors

Several arguments and counter arguments blur the effect of the democracy on environmental politics and environmental quality. Some of the arguments suggest that there is a positive correlation between democracy and environmental quality. A central argument is that many forms of environmental degradation gain the few, but also harm the many. As long as elites tend to gain from environmental degradation, while the costs are spread throughout the public, the sharing of power that appears in democratic regimes could act to curb the degrading activities of the few. Other significant reasons behind this positive correlation include (Winslow, 2005: 772):

(1) The accountability of leaders, which makes it difficult for them to personally gain from environmental degradation;

(2) Public involvement in policy making, which increases the likelihood of environmental issues being identified and resolved;

(3) Access to information, allowing for public to be more aware of environmental problems;

(4) the presence of non-governmental organizations that can work to help inform the public about environmental problems, can act as watchdogs on public agencies, and can directly lobby members of government;

(5) The availability of civil litigation as a tool to enforce environmental protection;

(6) International aspects of democracy, such as the interaction of democratic nations in sharing information about environmental problems and regulatory techniques, the development of international treaties and regulatory techniques, as well as the development of international treaties for global environmental problems.

In contrast, authoritarian regimes are relatively less pro-environment than democratic regimes. A central argument is as follows: authoritarian regimes are typically ruled by small elites that hold a much larger share of national income than most people in a democracy (Li & Reuveny, 2009: 937). Since, they use resources of their respective nation to create personal wealth and to redistribute income from their populations towards themselves. If the costs of stricter environmental policies are born disproportionately by the elites, as it would be the case with restrictions on polluting industrial activities, while the benefits are uniformly dispersed throughout the population, and therefore these elites would have little incentive to adopt and implement such policies. On the other hand, in democracies the median voter, who decides on public policy, faces lower costs from environmental policies relative to the economic and political elite. This makes the adoption and implementation of stricter environmental policies more likely in democratic regimes (Bernauer, 2009: 1356). Other significant reasons behind this negative correlation include (Winslow, 2005: 772):

(a) The lack of accountability for leaders;

(b) The concentration of power in small elite who might use this power to personally profit from activities associated with high levels of environmental degradation;

(c) Restrictions on the free flow of information; and

(d) The need for coercion and legitimacy, which in turn limits long-term investments in environmental quality. But, this does not mean that authoritarian regimes will never take steps to improve environmental quality. There are many examples of authoritarian regimes acting to improve environmental quality. Despite of their great efforts, authoritarian regimes have much worse records on environmental protection than democratic regimes.

The counter arguments claimed that democracy might not be the best type of government in order to protect environmental quality in all circumstances and that authoritarian regimes might be necessary to prevent ecological ruin (Winslow, 2005: 772). It fully does not necessarily hypothesize that democracy, as a regime type, is unable to protect environmental quality. Rather, it might be that certain aspects of democracy essential to protecting and improving environmental quality are failing. It might be that where environmental protection breaks down, a breakdown in these essential processes and functions of democracy can also be recognized. For instance, democratic systems can be corrupted by, among other things, a lack of rules on campaign contributions, and the high costs of being elected. Also, the effectiveness of democratic decision making has declined due to the increasing power of markets and bureaucracies (Winslow, 2005: 781).

The most significant reason behind this negative correlation is associated with the following debate: "just as environmental quality is not a homogeneous good, neither is democracy". Ignoring either type of pollutant does not produce a sufficient framework in order to check the efficiency of the democracy. More specifically, environmental quality is not a *homogenous good*, and therefore not all aspects of environmental quality are expected to respond equally to the sharing of power related to democratic regimes. Some environmental problems are more likely than others to be controlled in a democracy due to their different characteristics (Winslow, 2005: 781). It is assumed that the nature of the pollutant might affect the policy weights given to preferences, that is, the rate at which the preferred environmental policy is translated into actual policy (Farzin & Bond, 2006: 8).

One significant characteristics of the EKC hypothesis is the classification of the pollutants. It appears that "pollutants are classified by their zone of influence, or where their effects are felt most directly". In general, a local pollutant would be one for which the effects are felt near the source of emission, while a global pollutant would be one for which the effects are felt far the national boundaries (Meers, 2000: 1). For instance, many polluting industries, particularly energy-intensive industries, produce multiple pollutants that create global and local environmental problems. Particularly, the combustion of fossil fuels not only produces greenhouse gases, but also produces air pollutants with more localized effects (Silva & Zhu, 2009: 169). Typical examples of local pollutants are volatile organic compounds, particulate matter, sulfur oxides, and nitrous oxides, while typical examples of global pollutants are CFC's, carbon dioxide and other greenhouse gases (GHGs).

Similarly, one significant characteristics of the democracy is to generate somewhat different outcomes towards the case of global versus local pollutants. On one hand, local pollutants are subject to domestic environmental regulations (Silva & Zhu, 2009: 169-170), and more weights are obviously given to abatement policies aiming at local pollutants at low-income levels. This means that the main sufferers of these pollutants are the inner-city, low-income group and their damages become visible in a relatively short period (Farzin & Bond, 2006: 8). The logic is as follows: the environment is treated as a luxury good, subject to public demand with the help of the instruments of an advanced market. During the early stages of development, environmental effects make worse (Jorgenson & Clark, 2011: 227). In this case, the local residents bear all the costs of cleaning up the pollutant or living in a polluted environment (Meers, 2000: 1). However, as fortune within these societies changes, the value the public places on the environment will increase. Social interest starts to dominate self-interest. The public desire for enhancing quality of life, in large part expressed as consumer demand for 'green' products and services, put pressure on governments and businesses to invest in 'eco-friendly' technologies and commodities (Jorgenson & Clark, 2011: 227).

Partly drawing from environmental economics, in the case of local pollutants, the only possible way out of the ecological crisis is by going further into the process of democratic institutions. The forces of governments that are believed to move human society from its past of environmental degradation to sustainability are the institutions of modernity, including markets, industrialism, and technology. In developed societies, an 'ecological rationality' will take place, as environmental concerns are better incorporated into decision-making, and also ecological costs are weighed along with economic considerations. Thus, environmental degradation in terms of local pollutants, which have immediate and clear effects on the health or livelihood of many local residents, is not seen an inherent characteristics of continual economic development (Jorgenson & Clark, 2011: 227-228). Technically, there would be an inverted-U curve, i.e., the notion that local air pollution increases at initial levels of economic development and reduces after a turning point of advanced economic development.

On the other hand, less weight might be given to policies aiming to mitigate global air pollutants. That is, policies aiming to improve environmental facilities that benefit, and support the lifestyle of, the rich receive less weight, and also this is more likely to be the case the more democratic is the political regime of a society (Farzin & Bond, 2006: 8). The logic is as follows: global pollutants develop slowly and over long periods of time with distant, unclear or uncertain effects or that influence fewer citizens (Winslow, 2005: 781), but are responsible for the damage done in the upper atmosphere. These pollutants are usually related to problems such as increasing global temperatures or the greenhouse effect. In this case, the effects are more indirect, and so the total costs of the pollution would not be felt directly by the local residents, but shared by all the nations that are affected (Meers, 2000: 1-2). Thus, the functions of government will be inefficient to clean up or block emissions which will experience a sustained period of growth, and will be a big challenge to the promise of achieving stated international emission reductions targets as well as to the duty which may need to be fulfilled in the future (Yin et al., 2015: 98). Technically, this mean there would be either an inverted-U curve with a very high turning point or a curve that increases without a turning point (Meers, 2000: 2).

Based on the theories explained above, hypothesis 6 of this thesis investigates what kind of relationship exists between global warming and air pollution caused by the dimensions of democracy. Following Winslow's line of argumentation, in view of the arguments (i)-(ii) noted above, on the contrary to the authoritarian regimes, democratic regimes may have short planning horizons due to political myopia. This implies that they are unable to solve many forms of environmental degradation that develop slowly and over long periods of time (i.e., climate change, biodiversity, air and water pollution). Therefore, the social costs of current economic behavior and political choices often materialize over the long term and burden future generations and future politicians. Democracies may worsen environmental quality relative to authoritarian regimes where political leaders do not face frequent re-election as well as can take, if they wish to, more costly decisions (stricter environmental regulation and policies) with longer-term benefits without fear of been punished by myopic voters. These arguments set up the sixth testable hypothesis:

Hypothesis 6: More democratic nations increase the level of global warming and air pollution, ceteris paribus.

Although democracy is a heavily debated concept, it is not an easy variable to measure. There exist three widely utilized democracy indices for measuring levels of democracy of a nation: the Polity index (developed by the Integrated Network for Societal Conflict Research of the University of Maryland; Marshall and Jaggers 2002), the Freedom House Index (2000), and the Vanhanen Index (2005). Each index represents every year an annual democracy score for a nation. The three indices share two common characteristics: the first, they are limited to a procedural understanding of democracy, and do not mark more substantial interpretations of democracy, i.e., deliberative democracy; the second, they assume that democracy can and should be recorded in categories or even metrically, rather than dichotomously (Buitenzorgy & Mol, 2011: 61-62).

Following You et al. (2015), it is used the indicator that is taken directly from the Polity IV database, maintained by the University of Maryland and the George Mason University. The variable employed is the aggregate indicator of democracy from the Polity IV database (Polity2). This variable captures the regime authority spectrum on a 21-point scale ranging from -10 (fully non-democratic) to +10 (fully democratic). Munck and Verkuilen (2002) presented a comprehensive summary of democracy measure. They argued that all available indices for democracy have substantial drawbacks in conceptualization, measurement, and aggregation. Of these indicators, the Polity IV variable has better intercoder reliability, clearer and detailed coding rules. Similarly, Buitenzorgy and Mol (2011) argued that the Polity IV index has been one of the most comprehensive indexes. Moreover, the Polity IV index has been employed in nearly every study of the effects of democracy on environmental quality, and thus provides a useful benchmark for the global warming model in this thesis (You et al., 2015: 198).

As a test for robustness, an alternative measure of democracy is used for air pollution model. This indicator is the Freedom House Political Rights Index and Civil Liberties Index, published by the Freedom House since 1973, which rates every nation of the world on a 1-7 scale for level of political freedom and level of civil liberties, where 1 indicates the highest degree of freedom and 7 the lowest degree of freedom (Winslow, 2005: 774). Following You et al. (2015), it is used a simple sum of these two indices as a proxy for the aggregate democracy level. Total ratings range from 2 to 14, 2 being the most democratic and 14 being the least (Winslow, 2005: 774). The FH measure has been used either as a primary measure or as a robustness check on any other measure used as the principal measure in nearly every study of the effects of democracy on environmental quality, and therefore provides a useful benchmark for the air pollution model in this thesis (You et al., 2015: 198).

Based on EKC theory, it is assumed that there might be an inverted U-shaped relationship between economic development and both CO_2 and SO_2 emissions: five conditional variables including, coal and alternative (non-fossil) sources of electricity production, energy efficiency, the industry share in GDP, and governance factors, exert a moderating effect on this relationship. The worldwide nations are facing up to the rapid economic growth, industrialization and urbanization process with rigid demand for energy. In a fairly long period of time, economic growth will remain highly dependent on coal-dominated energy consumption and production structure; particularly, CO_2 emissions may also experience sustained growth over a long period afterwards. With increasing levels of economic development, the needs for clean environment of the residents will be growing. Both the national and international governments will also continue to carry out the adjustment of economic structure, to optimize and upgrade the industrial structure, to adopt new technologies to improve energy efficiency, as well as to develop new energy sources and alternative energy to optimize the energy consumption and production structure. These initiatives will help to reduce both CO_2 and SO_2 emissions. In short, to reflect the influence of these variables on both low carbon and low sulfur development, the following conceptual models are developed (see Fig. 17):

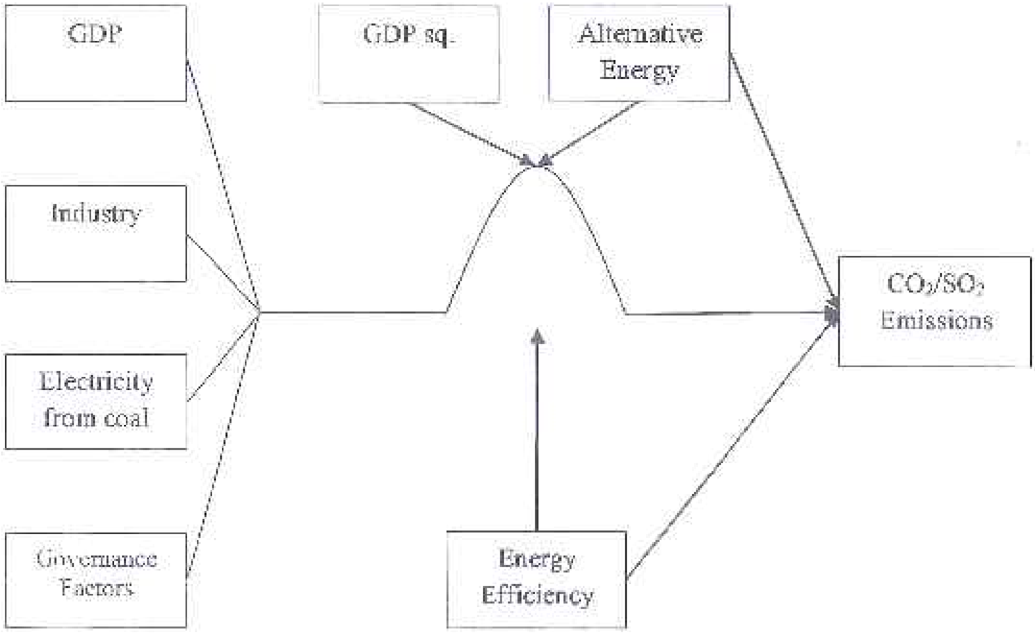


Fig. 17. Conceptual Model for Inverted U-Shaped Trajectory [Source: Own elaboration based on environmental literature].

On the other hand, such inverted-U relationships may not hold in the long run. For instance, Pezzey (1989) and Opschoor (1990) introduced a so-called "N-shaped" curve which exhibits the same pattern as the inverted-U curve initially, but beyond a certain income level the relationship between environmental degradation and income becomes positive again. Thus, de-linking is thought to be a temporary phenomenon. The logic is as follows: once technological efficiency improvements in resource use or abatement opportunities are exhausted or become too expensive, further income growth will result in net environmental degradation (De Bruyn et al., 1998: 163). In short, to reflect the influence of these variables on both low carbon and low sulfur development, the following conceptual models are developed (see Fig. 18):

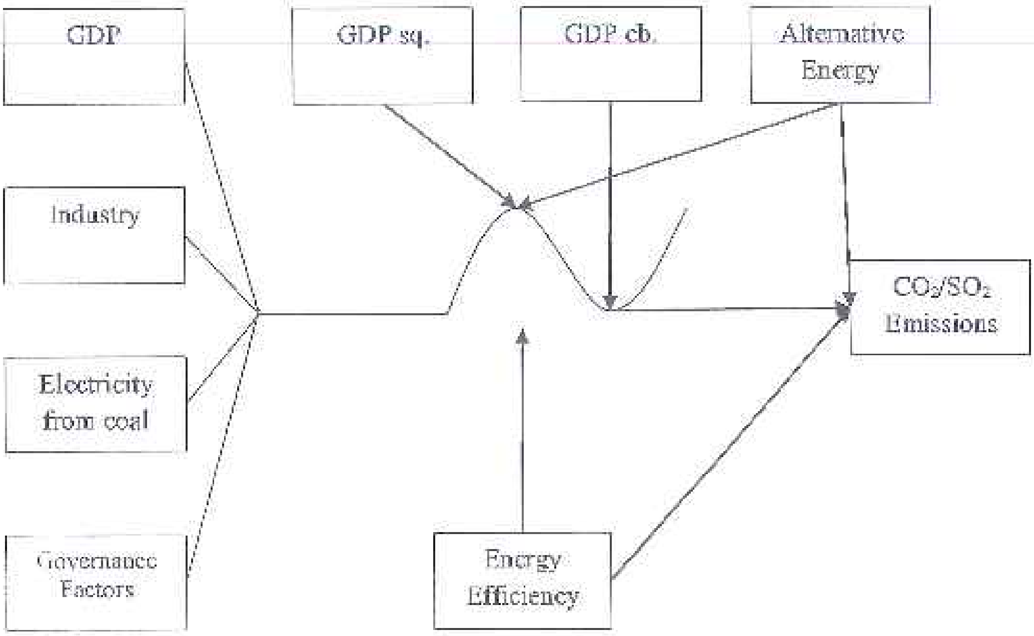


Fig. 18. Conceptual Model for N-Shaped Trajectory [Source: Own elaboration based on environmental literature].

CHAPTER 3

EMPIRICAL METHODOLOGY

3.1. Data and Variables

This thesis begins the analysis by estimating the EKC for CO_2 and SO_2 emissions for annual data covering 119 nations from 1990-2011 and covering 118 nations from 1990-2005, respectively. Table B1 and B2 in appendix list the nations and sample period included. These data are utilized for the panel data analysis, to achieve the previously mentioned goals of this thesis; a panel model is established, defining firstly the dependent variable as a nation's carbon dioxide emissions (global pollutant) as an indicator of global warming and sulfur dioxide emissions (local pollutant) as an indicator of air pollution.

The first dependent variable, which is an emission of CO_2 that is a "global pollutant" frequently analyzed due to its suitable characteristics; it is a by-product of energy consumption with strong global effects, available abatement technologies, and different regulations across nations. A deeper investigation of CO_2 emissions contributes to a better understanding of two main environmental issues: greenhouse gas effect and global climate change that poses serious threats to the region's environment, ecological and socio-economic systems (Nema et al., 2012: 2330). The second dependent variable, which is emissions of SO_2 that is a "local pollutant" frequently analyzed due to its suitable characteristics; it is a by-product of goods production with strong regional effects, available abatement technologies, as well as different regulations across nations (Grether et al., 2010: 714). By the same token, a deeper investigation of SO_2 emissions contributes to a better understanding of three environmental issues: local air pollution and smog, acid rain and dry deposition, as well as global climate change (Stern, 2006: 207).

CO_2 is generally defined as a linear function of fossil fuel combustion and cement manufacturing. The amount of carbon dioxide emissions is determined by the use of fossil fuels as a feedback and the chemical composition of the fuel source. That is, each of fossil fuels is weighted by its corresponding conversion ratio, which is determined by the chemical properties of the fuel. In turn, the sum of the weighted total fuel consumption yields an estimate of CO_2 emissions. This estimate of CO_2 emissions, based on energy consumption, is frequently used as proxy for actual emissions (i.e., it is used by the World Bank's World Development Indicators and the Carbon Dioxide Information Analysis Center within the U.S. Department of Energy), since carbon dioxide emissions are highly related to energy consumption (Zhao et al., 2014: 3). Fig. 19 shows annual estimates for the global and regional anthropogenic carbon dioxide emissions metric tons per capita from 1990 to 2011.

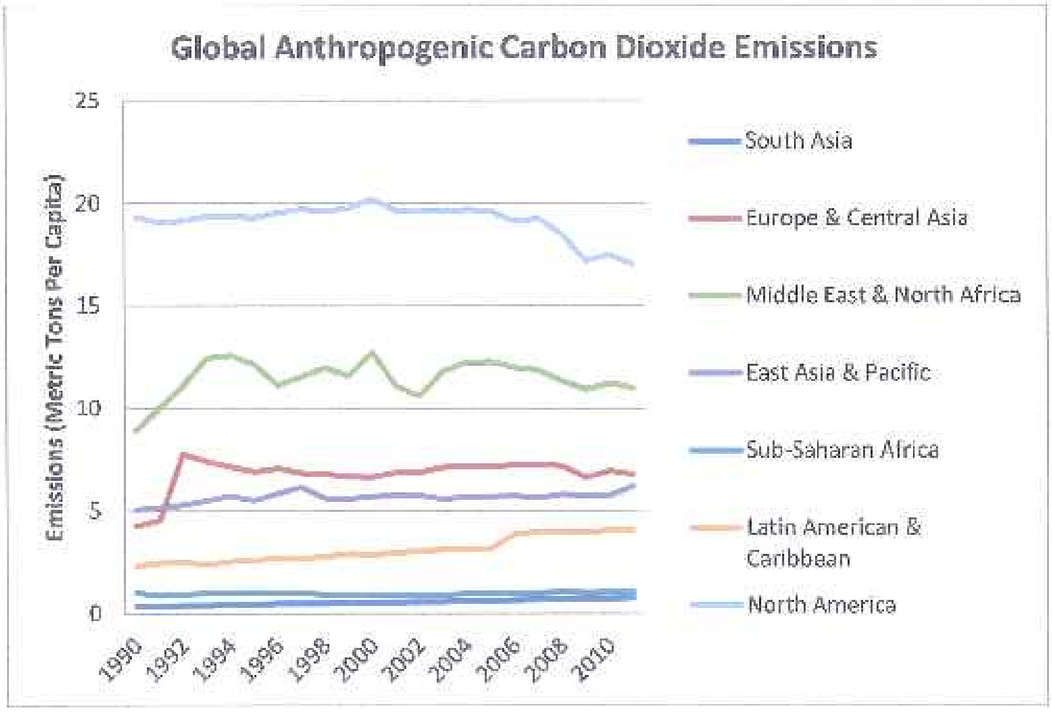


Fig. 19. Global Carbon Dioxide Emissions Metric Tons Per Capita by Region [Source: Own elaboration based on World Bank Data].

SO_2 is the predominant anthropogenic sulfur-containing air pollutant (Speidel et al., 2007: 2427) with coal and crude oil deposits commonly containing 1-2% sulfur by weight (Smith et al., 2011: 1101). Smith et al. (2011) provided annual estimates of anthropogenic global and regional sulfur dioxide emissions spanning the period 1850-2005 by using a bottom-up mass balance method, calibrated to country-level inventory data. It also includes emissions by nation and by source category (coal, petroleum, biomass combustion, smelting, fuel processing, and other processes). This data set is developed at the Pacific Northwest National Laboratory (PNNL) and the maps are produced at the Center for International Earth Science Information Network (CIESIN). The data and maps created using the data set are distributed by CIESIN at Columbia University. Fig. 20 shows annual estimates for the global and regional anthropogenic sulfur dioxide emissions metric tons per capita from 1990 to 2005.

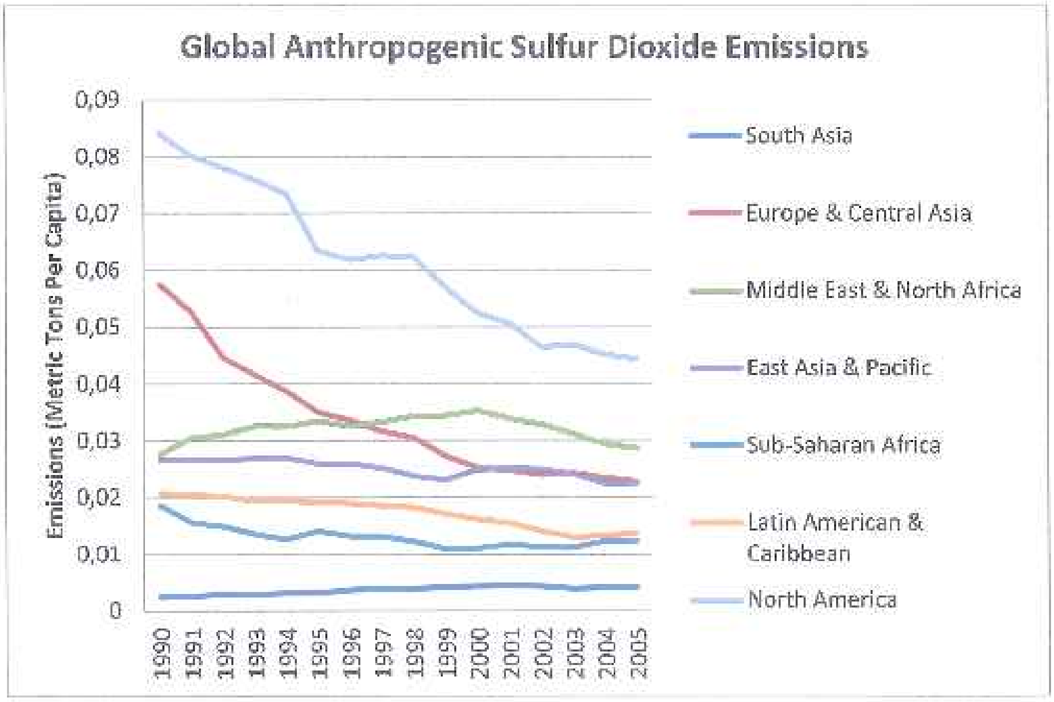


Fig. 20. Global Sulfur Dioxide Emissions Metric Tons Per Capita by Region [Source: Own elaboration based on CIESIN Data].

Drawing on the aforementioned general theoretical foundations, the empirical setup formally investigates the determinants of emissions, where carbon dioxide emissions per capita (CO_2pc) and sulfur dioxide emissions per capita (SO_2pc) capture pollution in the *i*th nation. In this context, a nation's emissions are a function of two main factors: (1) *economic*: (i) the level of economic activity represented by real per capita GDP; (ii) the structure of the economy measured by the industry sector's share in GDP; (iii) the energy mix measured by the ratio of alternative and nuclear energy to total energy use and the ratio of coal sources in total electricity production; (iv) energy efficiency measured by log of GDP per unit of energy use; (2) *governance* measured by the difference between the sub-indexes for democracy and autocracy (polity2), or alternatively measured by the sum of the Freedom House Political Rights and Civil Liberties Indices (freedom). Therefore, the explanatory variables are consistent with environmental economics literature (see Fig. 21).

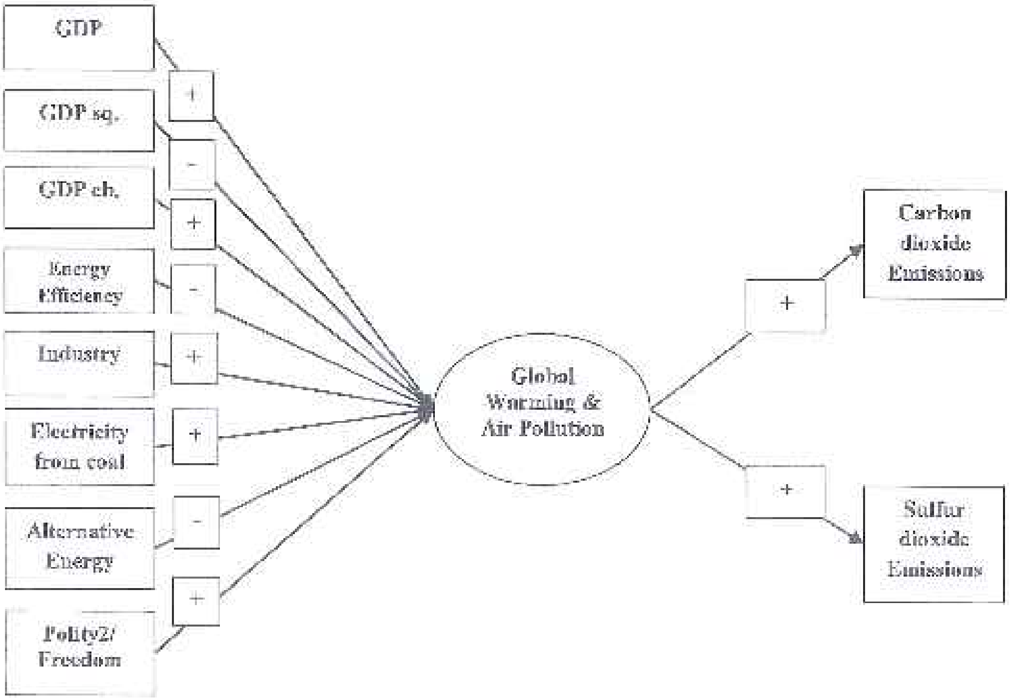


Fig. 21. Path Diagrams of the Global Warming and Air Pollution Indicators (Baseline Specification) [Source: Own elaboration based on environmental literature].

Based on these explanations, indicators of global warming (CO_2) and air pollution (SO_2) are modeled as a function of log of real gross domestic product per capita, the structure of the economy, electricity from coal sources and alternative energy, energy efficiency, the difference between the sub-indexes for democracy and autocracy, or alternatively the sum of the Freedom House Political Rights and Civil Liberties Indices. In order to investigate the most convincing model of EKC between the inverted U-shaped scenario and the N-shaped scenario, this thesis builds two specifications as follows:

Specification 1a:

$$Emissions\ CO_2 = f[ln(RGDPPCPPP)(+),\ ln(RGDPPCPPP)^2(-), ln(energy\_efficiency)(-), alternative\_energy\ (-), coal\_energy\ (+), indus(+), polity2\ (+)].$$

Specification 1b:

$$Emissions\ CO_2 = f[ln(RGDPPCPPP)(+),\ ln(RGDPPCPPP)^2(-),\ ln(RGDPPCPPP)^3(-), ln(energy\_efficiency)(-), alternative\_energy\ (-), coal\_energy\ (+), indus\ (+), polity2\ (+)].$$

Specification 2a:

$$Emissions\ SO_2 = f[ln(RGDPPCPPP)(+),\ ln(RGDPPCPPP)^2(-), ln(energy\_efficiency)(-), alternative\_energy\ (-), coal\_energy\ (+), freedom\ (+), indus\ (+)].$$

Specification 2b:

$$Emissions\ SO_2 = f[ln(RGDPPCPPP)(+),\ ln(RGDPPCPPP)^2(-),\ ln(RGDPPCPPP)^3(-), ln(energy\_efficiency)(-), alternative\_energy\ (-), coal\_energy\ (+), freedom\ (+), indus\ (+)].$$

The 1.1a and 1.2b equations are the panel models that contain the fixed country and time effect, while the 2.1a and 2.2b equations are the GMM equations, which are significantly a dynamic panel equation that contain dynamic effects (LCO_{2it-1}), country-fixed effects (υ), time-fixed effects (ζ) and an error term (ε). t represents the time period t (1990-2011), and i is the cross section (119 nations). The β_{1i}…… β_{11i} represent the slope coefficients, α is the constant, and ε is the error term. $LCO_{2(it)}$ is the log of carbon dioxide emissions in metric tons per capita.

***Equation 1.1a*:**

$$\begin{aligned} LCO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp^2_{it} \\ & + \beta_3 lenergy\_efficiency_{it} + \beta_4 alternative\_energy_{it} \\ & + \beta_5 coal\_energy_{it} + \beta_6 indus_{it} + \beta_7 polity2_{it} + \upsilon_i + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

***Equation 1.2b*:**

$$\begin{aligned} LCO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp^2_{it} + \beta_3 lrgdppcppp^3_{it} \\ & + \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ & + \beta_6 coal\_energy_{it} + \beta_7 indus_{it} + \beta_8 polity2_{it} + \upsilon_i + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

***Equation 2.1a*:**

$$\begin{aligned} LCO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp^2_{it} + \beta_3 lenergy\_efficiency_{it} \\ & + \beta_4 alternative\_energy_{it} + \beta_5 coal\_energy_{it} + \beta_6 indus_{it} \\ & + \beta_7 polity2_{it} + \alpha \mathrm{LCO}_{2(it-1)} + \upsilon_i + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

***Equation 2.2b*:**

$$\begin{aligned} LCO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp^2_{it} + \beta_3 lrgdppcppp^3_{it} \\ & + \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ & + \beta_6 coal\_energy_{it} + \beta_7 indus_{it} + \beta_8 polity2_{it} + \alpha \mathrm{LCO}_{2(it-1)} + \upsilon_i \\ & + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

The 1.3a and 1.4b equations are the panel models that contain the fixed country and time effect, while the 2.3a and 2.4b equations are the GMM equations, which are significantly a dynamic panel equation that contain dynamic effects (LSO_{2it-1}), country-fixed effects (υ), time-fixed effects (ζ) and an error term (ε). t represents the time period t (1990-2005), and i is the cross section (118 nations). The β_{1i}…… β_{11i} represent the slope coefficients, α is the constant, and ε is the error term. $\mathrm{LSO}_{2(it)}$ is the log of sulfur dioxide emissions in metric tons per capita.

***Equation 1.3a*:**

$$\begin{aligned} LSO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 \\ & + \beta_3 lenergy\_efficiency_{it} + \beta_4 alternative\_energy_{it} \\ & + \beta_5 coal\_energy_{it} + \beta_6 freedom_{it} + \beta_7 indus_{it} + \upsilon_i + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

***Equation 1.4b*:**

$$\begin{aligned} LSO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 + \beta_3 lrgdppcppp_{it}^3 \\ & + \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ & + \beta_6 coal\_energy_{it} + \beta_7 freedom_{it} + \beta_8 indus_{it} + \upsilon_i + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

***Equation 2.3a*:**

$$\begin{aligned} LSO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 \\ & + \beta_3 lenergy\_efficiency_{it} + \beta_4 alternative\_energy_{it} \\ & + \beta_5 coal\_energy_{it} + \beta_6 freedom_{it} + \beta_7 indus_{it} + \alpha \mathrm{LSO}_{2(it-1)} + \upsilon_i \\ & + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

***Equation 2.4b*:**

$$\begin{aligned} LSO_{2it} = {} & \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 + \beta_3 lrgdppcppp_{it}^3 \\ & + \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ & + \beta_6 coal\_energy_{it} + \beta_7 freedom_{it} + \beta_8 indus_{it} + \alpha \mathrm{LSO}_{2(it-1)} + \upsilon_i \\ & + \zeta_{it} + \varepsilon_{it} \end{aligned}$$

The variables in use – including expected sign and data source – are summarized in Table 3.

Table 3. List of Variables and Their Sources.

Variable	Expected Sign	Description	Source
LCO_2PC		Log of CO_2 emissions in metric tons per capita	WDI (2015)
LSO_2PC		Log of SO_2 emissions in metric tons per capita	SEDAC (2011)
LGDPPCPPP	+	Log of real GDP per capita (constant 2011 international $ ppp)	WDI (2015)
$LGDPPC^2PPP^2$	-	Squared log of real GDP per capita	WDI (2015)
$LGDPPC^3PPP^3$	+	Cubic log of real GDP per capita	WDI (2015)
LENERGY_EFFICIENCY	-	Log of GDP per unit of energy use (constant 2011 PPP $ per kg of oil equivalent)	WDI(2015)
ALTERNATIVE_ENERGY	-	Alternative and nuclear energy (% of total)	WDI (2015)
COAL_ENERGY	+	Electricity production from coal sources (% of total)	WDI (2015)
FREEDOM	+	Sum of the Freedom House Political Rights and Civil Liberties Indices	Freedom House (2016)
INDUS	+	Industry value added (% of GDP)	WDI (2015)
POLITY2	+	The difference between the sub-indexes for democracy and autocracy	Marshall and Gurr (2014)

*This thesis uses yearly observations for 119 nations for the period 1990-2011 for LCO_2pc and also uses yearly observations for 118 nations for the period 1990-2005 for LSO_2pc.

3.2. Modeling Strategy

As cited previously, the econometric technique utilized plays a key role in finding turning points and designing the proper policy implications (Park & Lee, 2011: 5844). The particular interest in this regard is whether the estimated turning point is economically meaningful or just a statistical artifact. If this turning point is too high it would represent that the EKC-relationship is only a statistical artifact and not recommendable to wait (Lamla, 2009: 140). Thus, this thesis attempts to analyze the panel data using three models, a fixed effects model, a random effects model, and a generalized method of moments (GMM) model which have different assumptions on intercept and slope. The estimation of the models for both CO_2 and SO_2 are completed by EVIEWS 8.

The fixed and random effects models are based on the assumption that the intercept (an individual effect) varies in every nation (Park & Lee, 2011: 5844). On the one hand, the fixed effects model portions of specifications are controlled using orthogonal forecasts. These forecasts of projections remove the specific means from the cross-sections and the period from the dependent variables and the exogenous regressors and thereby utilizing the quantified regression using the demeaned data (Al-mulali et al., 2015: 317). That is to say, the fixed effects model assumes time-independent effects for each entities and nations the need for controlling unobserved heterogeneity when it is constant over time (Park & Lee, 2011: 5844). The advantage of using the fixed effects model is that it can eliminate the bias problems arising from the omitted variables that do not change over time. On the other hand, the random effects model assumes that the equivalent effects of the cross-section effect vectors and the time period effect vectors are significantly uncorrelated (Al-mulali et al., 2015: 317). In other words, the random effects model is based on the assumption that the individual effects are randomly distributed. While the fixed effects model employs dummy variables on the assumption that there is correlation between the independent variable and the error term, the random effects model assumes that there is no correlation between the two (Park & Lee, 2011: 5844).

In order to determine the optimal level, the Hausman (1978) test is utilized, as the test compares the random and fixed effects estimates of coefficients (Al-mulali et al., 2015: 317). In this case, the null hypothesis is that a constant term is not related to independent variables (Park & Lee, 2011: 5844). The Hausman test is based on Chi-square statistics; if the Chi-square statistics is significant, implying that the null hypothesis is rejected, the random effects model is not reliable, and the fixed effects model should be selected. Nevertheless, both the fixed and the random effect are weak in controlling the correlation and the heterogeneity between the instruments' variables and disturbance (Al-mulali et al., 2015: 317).

The fixed and random effects models assume slope homogeneity based on the assumption that the functional form of the relationship between income and global warming as well as air pollution is the same for each nation. This assumption may be unrealistic and restrictive due to given differences in physical (geography or climate) and social (culture, economic structure, or political system) features embedded in each nation (Park & Lee, 2011: 5844). In contrast to the fixed and random effects models, which estimate variation only in the intercept, not in the slope, the GMM model may provide a solution by taking into a number of considerations: firstly, the use of panel data introduces a great deal of unobserved heterogeneity; secondly, it is inappropriate to assume that cross-section units are independent since some nations in the panel are susceptible to global common shocks and spillover effects; thirdly, the unobserved non-stationary common factors may influence some or all of the variables in the panel (El Anshasy & Katsaiti, 2014: 87).

The GMM is a common method for estimating parameters in statistical models. Generally, it is applied in the setting of semi parametric models, where the parameter of interest is finite-dimensional, whereas the full shape of the distribution function of the data may be unknown, and thus the maximum likelihood estimation is not applicable. The GMM belongs to a number of estimators, recognized as M-estimators, which can be identified by minimizing a number of the functions of a criterion. Also, the model is significantly a robust estimator that does not require information about the precise distribution of the disturbances; it provides a number of estimates that can eliminate the correlation and the heterogeneity between the instruments' variables and disturbance (Al-mulali et al., 2015: 317).

This thesis uses the lagged difference and the constant for the variables as instruments control multicollinearity, moreover, the validity of the instruments' variables for the GMM models is examined by utilizing the Sargan test. This test is significantly a Chi-square test that determines whether the residuals are correlated with the instrument variables. If we cannot reject the null hypothesis of the Sargan test, there is no indication of instrument misspecification; therefore, the instruments are valid.

One more issue regarding panel data analysis is that considering time series properties recently held spotlight of the EKC literature. Some recent studies highlight the need for considering nonstationary variables and cointegration among them, in contrast to the existing studies of the EKC, which presuppose that the data are stationary in the time-series dimension. Consideration of the time series properties is essential, since whether panel data are stationary or nonstationary determines the appropriate methods to explore the EKC hypothesis; if the results of unit root and cointegration tests show that series are nonstationary and a linear combination of them is also nonstationary, there is no cointegration, the EKC regression can lead to spurious results (Park & Lee, 2011: 5844). Thus, the most significant step in an econometric analysis is to test the stationarity of the variables, as a variable cannot be used in the analysis if it is not stationary. A variable is assumed to be stationarity if its mean and autocovariances do not depend on time (Al-mulali et al., 2015: 317).

3.3. Panel Unit Root

The first main difference between unit root tests in time series data and panel data regards the issue of heterogeneity. In the time series case, heterogeneity is not an issue, since unit root hypothesis is tested in a given model for a given individual, but in a panel data context, the panel is heterogeneous and the panel unit root tests must take into account this heterogeneity, even if tests depend on pooled estimates of the autoregressive parameters can be consistent against a heterogeneous alternative. This notion of heterogeneity has been a central point in the econometrics of panel data. Hence, the issue of the specification of the alternative created the first departure in the literature. After the seminal paper presented by Levin and Lin (1992, 1993), Levin, Lin and Chu (2002) depend on a pooled estimator of the autoregressive parameter, numerous tests depend on a heterogeneous specification of the alternative have been presented by Im, Peseran and Shin (1997), Maddala and Wu (1999), Choi (2001) and Hadri (2000) (Hurlin & Mignon, 2007: 2).

Table 4. Summarizing of Panel Unit Root Tests.

Panel Unit Root Tests	
First Generation	**Cross-sectional independence**
1. Nonstationary tests	Levin and Lin (1992, 1993)
	Levin, Lin and Chu (2002)
	Harris and Tzavalis (1999)
	Im, Pesaran and Shin (1997, 2002, 2003)
	Maddala and Wu (1999)
	Choi (1999, 2001)
2. Stationarity tests	Hadri (2000)
Second Generation	**Cross-sectional dependencies**
1. Factor structure	Bai and Ng (2001, 2004)
	Moon and Perron (2004)
	Philips and Sul (2003)
	Pesaran (2003)
	Choi (2002)
2. Other approaches	O'Connell (1998)
	Chang (2002, 2004)

[Source: Hurlin & Mignon, 2007, p. 3]

Panel unit root tests have undergone a transformation with respect to first generation and second generation unit root tests through the recent developments in the literature of econometric techniques. This differentiation is based on given the cross-sectional dependence in the panel data (see Table 4). First generation panel unit root tests assume that the cross-sections in the panel data are independent, while the second generation panel unit root tests relax this assumption. On one hand, if cross-sectional dependence is present in the data, application of the first generation panel unit root test may produce misleading results due to size distortions. On the other hand, if no cross-sectional dependence is present in the data, then application of the second generation panel unit root test may produce loss of power (Sinha, 2016: 4). In this thesis, the latter takes place, and hence, it is used the first generation panel unit root tests, namely, Fisher-type ADF and PP unit root tests introduced by Maddala and Wu (1999) and Choi (2001).

As it was mentioned above, the panel unit root tests depend on heterogeneous model consist in testing the significance of the results from *N* independent individual tests. In this regard, IPS utilizes an average statistic, but there is an alternative testing strategy depends on combining the observed significant levels from the individual tests. This approach depend on *p*-values has a long history in meta-analysis. In panel unit root tests, such a strategy depend on Fisher (1932) type tests, was first employed by Choi (2001) and Maddala and Wu (1999). They test the same null and alternative hypotheses as IPS (Hurlin & Mignon, 2007: 6):

$H_0 = \rho_i = 0$ for all $i = 1, \dots, N$ against the alternative hypothesis: $H_1 = \rho_i < 0$ for and $i = 1, \dots, N_1$ and $\rho_i = 0$ for $i = N_1 + 1, \dots, N$, with $0 < N_1 \leq N$.

The logic of the Fisher type test is very simple. This test takes into account pure time series unit root test statistics, i.e., ADF, Elliott-Rothenberg-Stock, Max-ADF, etc.). If these statistics are continuous, the corresponding p-values, denoted p_i, are uniform (0,1) variables. Consequently, under the crucial assumption of cross-sectional independence, the statistic introduced by Maddala and Wu (1999) defined as (Hurlin & Mignon, 2007: 6-7):

$$P_{MW} = -2\sum_{i=1}^{N}\log(p_i) \qquad \text{(eq. 1)}$$

This statistic has a chi-square distribution with $2N$ degrees of freedom (χ^2_{2N}), when T tends to infinity and N is fixed. Eviews reports both the asymptotic χ^2 and standard normal statistics using ADF and Phillips-Perron individual unit root tests. According to Banerjee (1999), the obvious simplicity of this test and its robustness to statistic choice, lag length and sample size make it very attractive. For large N samples, Choi (2001) introduced a similar standardized statistic (Hurlin & Mignon, 2007:7):

$$Z_{MW} = \frac{\sqrt{N}\left[N^{-1}P_{MW} - E[-2\log(p_i)]\right]}{\sqrt{Var[-2\log(p_i)]}} = -\frac{\sum_{i=1}^{N}\log(p_i)+N}{\sqrt{N}} \qquad \text{(eq. 2)}$$

This statistic corresponds to the standardized cross-sectional average of individual p-values. That is, under the cross-sectional independence assumption, the Lindberg-Levy theorem is sufficient to show that it converges to a standard normal distribution under the unit root hypothesis (Hurlin & Mignon, 2007:7).

3.4. The Panel Regression

Panel data refers to data sets consisting of multiple observations on each sampling unit. This could be constituted by pooling time-series observations across a variety of cross-sectional units, such as, nations, states, regions, firms, or randomly sampled individuals or households. There are some of the advantages of using panel data over cross-section or time series data. Obvious advantage of using panel data sets is their ability to control for individual heterogeneity. Panel data assumes that individuals, firms, states or nations are heterogeneous, while time-series and cross-section studies not controlling this heterogeneity that run the risk of obtaining biased results. Also, panel data studies provide more informative data with more variability, less collinearity among the variables, more degrees of freedom and more efficiency. With additional, more informative data researchers can get more reliable parameter estimates. In addition, panel data are better able to study complex issues of dynamic behavior. Moreover, panel data are better able to identify and measure effects that are simply not detectable in pure cross-sections and pure time-series data. Finally, panel data models allow researchers to design and test more complicated behavioral models than purely cross-section and time-series data (Baltagi, 2005: 4-5-6; Ullah et al., 1998: 1-2).

In contrast, panel data is not a "panacea" and will not solve all the problems that time series or a cross-section study could not handle. For an extensive discussion of problems that may arise in designing panel surveys, data collection and data management issues, distortions of measurement errors, selectivity problems (self-selectivity, nonresponse and attrition), and short time-series dimension as well as cross-section dependence. Macro panels on nations or regions with long time series that do not account for cross-country dependence may give rise to misleading inference. Consequently, accounting for cross-section dependence turns out to be essential and affects inference. Alternative panel unit root tests are suggested that account for this dependence (Baltagi, 2005: 7-8).

3.4.1. The Fixed Effects Model versus the Random Effects Model

The relationship between emission of pollutants (per-capita carbon dioxide and sulfur dioxide emissions), per-capita real GDP, alternative energy, coal energy, energy efficiency, industry, freedom or polity2 can be specified as follows:

Equation 1:

$$\begin{aligned} \mathit{lpollutant}_{it} = \beta_0 &+ \beta_1 \mathit{lrgdppcppp}_{it} + \beta_2 \mathit{lrgdppcppp}_{it}^2 \\ &+ \beta_3 \mathit{lenergy\_efficiency}_{it} + \beta_4 \mathit{alternative\_energy}_{it} \\ &+ \beta_5 \mathit{coal\_energy}_{it} + \beta_6 \mathit{freedom/polity2}_{it} + \beta_7 \mathit{indus}_{it} + u_{it} \end{aligned}$$

Equation 1.1:

$$\begin{aligned} \mathit{lpollutant}_{it} = \beta_0 &+ \beta_1 \mathit{lrgdppcppp}_{it} + \beta_2 \mathit{lrgdppcppp}_{it}^2 + \beta_3 \mathit{lrgdppcppp}_{it}^3 \\ &+ \beta_4 \mathit{lenergy\_efficiency}_{it} + \beta_5 \mathit{alternative\_energy}_{it} \\ &+ \beta_6 \mathit{coal\_energy}_{it} + \beta_7 \mathit{freedom/polity2}_{it} + \beta_8 \mathit{indus}_{it} + u_{it} \end{aligned}$$

Estimation of specification 1 and 1.1 for CO_2 and SO_2 emissions depends on the assumptions researchers make about the intercept, the slope coefficients, and the error term, u_{it}. There are several possibilities including (Gujarati, 2003, p. 640):

(i) Assume that the intercept and slope coefficients are constant across time and space and the error term captures differences over time and individuals.

(ii) The slope coefficients are constant but the intercepts varies over individuals.

(iii) The slope coefficients are constant but the intercepts varies over individuals and time.

(iv) All coefficients (the intercept as well as slope coefficients) vary over individuals.

(v) The intercept as well as slope coefficients vary over individuals and time.

Among them, one way to take into account the 'individuality' of each nation or each cross-sectional unit is to let the intercept vary for each nation but still assume that the slope coefficients are constant across nations. In order to see this, the models are written (1 and 1.1) for CO_2 and SO_2 emissions with β_{0i} as:

Equation 1.2:

$$\begin{aligned} lpollutant_{it} = \beta_{0i} &+ \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 \\ &+ \beta_3 lenergy\_efficiency_{it} + \beta_4 alternative\_energy_{it} \\ &+ \beta_5 coal\_energy_{it} + \beta_6 freedom/polity2_{it} + \beta_7 indus_{it} + u_{it} \end{aligned}$$

Equation 1.1.2:

$$\begin{aligned} lpollutant_{it} = \beta_{0i} &+ \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 + \beta_3 lrgdppcppp_{it}^3 \\ &+ \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ &+ \beta_6 coal\_energy_{it} + \beta_7 freedom/polity2_{it} + \beta_8 indus_{it} + u_{it} \end{aligned}$$

Notice that it has been put the subscript i on the intercept term to suggest that the intercepts of the nations in the sample might be different; the differences might be resulted from special features of each nation, including economic, demographic, governance and geographical conditions. In the literature, models (1.2 and 1.1.2) are known as the "fixed effects" (regression) model (FEM). The term 'fixed effects' is due to the fact that, although the intercept might differ across individuals (here a variety of nations), each individual's intercept does not vary over time; that is, it is *time invariant*. Notice that if it were to write the intercept as β_{0it}, it will suggest that the intercept of each nation or individual is *time variant*. It may be noted that the FEM given in such models assumes that the (slope) coefficients of the regressors do not vary across individuals or over time (Gujarati, 2003: 642).

Instead of treating intercept β_{0i} as fixed, now it is assumed that it is a random variable with a mean value of intercept β_0 (no subscript i here). Consequently, the intercept value for an individual nation can be expressed as:

$$\beta_{0i} = \beta_0 + \varepsilon_i \quad i = 1, 2, \dots, N \qquad \text{(eq. 2)}$$

where ε_i is a random error term with a mean value of zero and variance of σ_ε^2. What it is essentially explaining is that the nations included in the sample are a drawing from a much larger universe of such nations and that they have a common mean value for the intercept ($= \beta_0$) and the individual differences in the intercept values of each nation are reflected in the error term ε_i. In order to see this, the model (2) is substituted into (1.2 and 1.1.2), it could be obtained:

Equation 1.3:

$$\begin{aligned} lpollutant_{it} = \beta_0 &+ \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 \\ &+ \beta_3 lenergy\_efficiency_{it} + \beta_4 alternative\_energy_{it} \\ &+ \beta_5 coal\_energy_{it} + \beta_6 freedom/polity2_{it} + \beta_7 indus_{it} + \omega_{it} \end{aligned}$$

Equation 1.1.3:

$$\begin{aligned} lpollutant_{it} = \beta_0 &+ \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp_{it}^2 + \beta_3 lrgdppcppp_{it}^3 \\ &+ \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ &+ \beta_6 coal\_energy_{it} + \beta_7 freedom/polity2_{it} + \beta_8 indus_{it} + \omega_{it} \end{aligned}$$

where $\omega_{it} = \varepsilon_i + u_{it}$. In the literature, models (1.3 and 1.1.3) are known as the "random effects" (regression) model (REM) or "error components model" (ECM). The composite error term ω_{it} consists of two compoenents, ε_i, which is the cross-section, or individual-specific, error component, and u_{it}, which is the combined time series and cross-section error component. In other words, the term *error components model* derives its name, since the composite error term ω_{it} consists of two (or more) error components (Gujarati, 2003: 647).

Notice carefully the difference between FEM and ECM. In FEM each cross-sectional unit has its own (fixed) intercept value, in all N such values for N cross-sectional units, while in ECM, the intercept β_0 represents the mean value of all the (cross-sectional) intercepts and the error component ε_i represents the (random) deviation of individual intercept from this mean value. However, ε_i is not directly observable; thus, it is what is known as an "unobservable", or "latent", "variable" (Gujarati, 2003: 648).

Having discussed the fixed effects and the random effects models and the assumptions underlying them, this section is left with the daunting question, what are the criteria select the correct model specification. This is not as easy a choice as it might seem. Thus, the fixed versus random effects issue has generated a vivid debate in the biometrics and statistics literature which has spilled over into the panel data econometrics literature. On one hand, Mundlak (1961) and Wallace and Hussain (1969) were early proponents of the fixed effects model, on the other hand, Balestra and Nerlove (1966) were advocates of the random error component model (Baltagi, 2005: 18-19). The Hausman test which is based on the difference between the fixed and random effects estimators. It is regularly utilized to test whether random effects (RE) can be chosen, or whether fixed effects (FE) estimation should be chosen instead (Bell & Jones, 2014: 6). Applied researchers have interpreted a rejection as an adoption of the fixed effects model and nonrejection as an adoption of the random effects model (Baltagi, 2005: 19).

Nevertheless, it is problematic when the test is viewed in terms of fixed and random effects, and not in terms of what is actually going on in the data. Fielding (2004) argued that: it 'is simply a diagnostic of one particular assumption behind the estimation procedure usually associated with the random effects model ... it does not address the decision framework for a wider class of problems'. Clark and Linzer (2012) noted that: it is 'neither necessary nor sufficient' "to use the Hausman test as the sole basis of a researcher's ultimate methodological decision" (Bell & Jones, 2014: 6-7).

3.5. Dynamic Generalized Method of Moments

Indicators of environmental quality are likely to be correlated over time, since environmental quality changes cumulatively (Li et al., 2016: 140). In order to capture this dynamic nature of environmental quality, it is included the lagged term of the dependent variable (i.e., indicators of environmental quality for global warming and air pollution) in the empirical model of the Environmental Kuznets Curve (EKC). In addition, as discussed in previous empirical studies, environmental quality is affected not only by national income but also other important variables. Hence, the empirical model of EKC also includes some commonly used control variables in order to mitigate the potential for misspecification and biased estimation, as given by:

Equation 2:

$$\begin{aligned} lpollutant_{it} = \beta_0 &+ \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp^{\,2}_{it} \\ &+ \beta_3 lenergy\_efficiency + \beta_4 alternative\_energy_{it} \\ &+ \beta_5 coal\_energy_{it} + \beta_6 freedom/polity2_{it} \\ &+ \beta_7 indus_{it} + \alpha lpollutant_{(it-1)} + \gamma_i + \varepsilon_{it} \end{aligned}$$

Equation 2.1:

$$\begin{aligned} lpollutant_{it} = \beta_0 &+ \beta_1 lrgdppcppp_{it} + \beta_2 lrgdppcppp^{\,2}_{it} + \beta_3 lrgdppcppp^3_{it} \\ &+ \beta_4 lenergy\_efficiency_{it} + \beta_5 alternative\_energy_{it} \\ &+ \beta_6 coal\_energy_{it} + \beta_7 freedom/polity2_{it} \\ &+ \beta_8 indus_{it} + \alpha lpollutant_{(it-1)} + \gamma_i + \varepsilon_{it} \end{aligned}$$

where *pollutant* is the per-capita pollution indicator, represented alternatively by LCO_2pc and LSO_2pc, and *lrgdppcppp*, $lrgdppcppp^2$, $lrgdppcppp^3$, *lenergy_efficiency*, *alternative_energy*, *coal_energy* and *indus* represent economic factors, *freedom* and *polity2* represent governance factors, $\gamma_i$captures the provincial fixed effects (due to the cross-province differences in industrial structure, culture and climate, etc.); ε_{it} is the error term.

Under the dynamic specification in Eq. (2), the EKC hypothesis is supported if $\beta_1 > 0$ and $\beta_2 < 0$; inverted U-formed quadratic relationship (EKC relationship). Under the dynamic specification in Eq. (2.1), the EKC hypothesis is supported if $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$; cubic polynomial N-formed EKC relationship. Even though both equations can be estimated by the conventional methods of fixed-effects and random-effects regressions, these estimations would produce biased results due to the endogeneity caused by the lagged dependent variable ($\alpha lpollutant_{(it-1)}$). For this reason, it is employed the GMM approach, which is first put forth by Hansen (1982) and later refined into the difference GMM (GMM-DIF) estimator by Arellano and Bond (1991). The basic idea of the GMM-DIF approach is using a group of lagged explanatory variables as instruments for the corresponding variables in the difference equation (Li et al., 2016: 141).

GMM-based approaches have important advantages over other panel data methods at least three reasons. The first reason, the use of instrumental variables in the GMM procedure allows parameters to be estimated consistently in models with endogenous right-hand-side variables, for example, GDP or energy consumption. The second reason, estimates will no longer be biased by omitted variables that are constant over time-country-specific effects. The third reason, even in the presence of transient measurements errors, the use of instruments potentially allows consistent estimation (Marrero, 2010: 1359).

The GMM-DIF approach, on the other hand, has important finite sample bias problems when variables are highly persistent, which is the case of GHG emissions, GDP and energy time series. Under these conditions, lagged levels of the variables are only *weak* instruments for subsequent first-differences, and also the GMM-DIF estimator would be poorly behaved. Arellano and Bover (1995) and Blundell and Bond (1998) argued that the weak instrumental variable problem may be unavoidable for the GMM-DIF and further presented an alternative GMM procedure, the system GMM (GMM-SYS). This procedure estimates a system of equations in both first-difference and levels, where the instruments in the level equations are lagged first-differences of the variables (Marrero, 2010: 1359).

In regard to the dynamic panel data models, Bond (2002) argued that the lagged dependent variable is correlated with the stochastic error term, which results in endogeneity. In other words, the ordinary least squares (OLS) level estimator is biased upward, whereas within groups tend to give a downward-biased estimate of the coefficient on the lagged dependent variable. Consequently, there is potential endogeneity for the independent variables. With this in mind, GMM estimators work well for panel data with large sample size and small time span, since they can use information from both difference and level equations. Corresponding to different weight matrixes, GMM estimators can be separated into one-step GMM estimators and two-step GMM estimators (Ren et al., 2014: 129).

In comparison with one-step estimators, two-step GMM estimators are less likely to be affected by heteroskedasticity. On the other hand, the presence of a finite sample might yield significant downward biased standard errors and skew the inferences. Windmeijer (2005) argued that the biases can be corrected by observing the extra variation in small samples (Ren et al., 2014: 129). By this implication, it is used robust two-step GMM procedure to calculate the standard errors. As two-step GMM estimators entail testing the validity of the instruments and whether there are serial correlations among the residuals, the Sargan test is used to assess the validity of the instruments. More specifically, the Sargan test is distributed chi-squared with degrees of freedom equal to the number of moment restrictions minus the number of parameters estimated under the null hypothesis that moment conditions are valid. However, the Sargan test is less meaningful as it requires that the error terms be independently and identically distributed, which is not expected in my case (Marrero, 2010: 1359). In addition, it is conducted tests in autoregressive models AR(1) and AR(2) to learn whether the residuals are serially correlated.

CHAPTER 4

EMPIRICAL RESULTS

4.1. Descriptive Statistics

In order to get some idea of both the CO_2 and SO_2 data used, they are plotted in the following two figures, respectively (see Fig. 22). The results of descriptive statistics on variables are summarized in Table 5A and Table 5B, respectively. The number of valid observations is 2573 for CO_2 and 1888 for SO_2, and the average emission volume of CO_2 and SO_2 is 0,879804 and -4,453198 metric ton per capita, respectively, demonstrating different quantities although there are considerable similarities between the minimum values. Also, the correlation analysis shows that none of correlation coefficients between any two independent variables exceed 0,6, indicating variables might not cause a severe multicollinearity problem (see Table 6A and Table 6B).

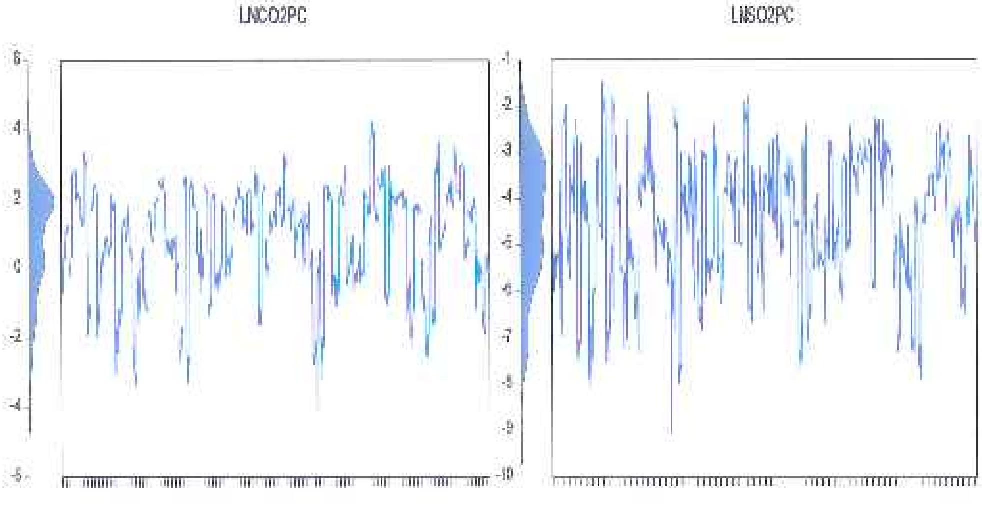


Fig. 22. Log of CO_2 and SO_2 Emissions in Metric Tons Per Capita, respectively.

Table 5A. Descriptive Statistics for LCO_2pc.

Variables	Min.	Max.	Mean	Std. deviation
LCO_2PC	-4,009917	4,229760	0,879804	1,489717
LGDPPCPPP	3,976238	11,80647	9,095227	1,167378
$LGDPPC^2PPP^2$	15,81047	139,3928	84,08539	20,85288
$LGDPPC^3PPP^3$	62,86618	1645,737	789,0095	285,8351
LENERGY_ EFFICIENCY	-0,180192	2,950608	1,925857	0,564978
ALTERNATIVE_ ENERGY	0,000000	99,43007	8,704171	12,45052
COAL_ENERGY	0,000000	100,0000	16,39472	26,02685
INDUS	6,298477	78,51812	31,75618	10,67268
POLITY2	-10,00000	10,00000	3,862136	6,588589

Table 5B. Descriptive Statistics for LSO_2pc.

Variables	Min.	Max.	Mean	Std. deviation
LSO_2PC	-9,073973	-1,468782	-4,453198	1,389628
LGDPPCPPP	3,976238	11,71287	9,003615	1,177092
$LGDPPC^2PPP^2$	15,81047	137,1913	82,44987	20,83933
$LGDPPC^3PPP^3$	62,86618	1606,903	766,7512	283,6400
LENERGY_ EFFICIENCY	-0,180192	2,942395	1,868202	0,578016
ALTERNATIVE_ ENERGY	0,000000	99,43007	8,675567	12,58532
COAL_ENERGY	0,000000	99,30796	16,65913	26,54205
FREEDOM	2,000000	14,00000	6,991398	3,832975
INDUS	6,298477	75,46798	31,57899	10,00969

Table 6A. Correlation Coefficients for LCO_2pc.

Correlation Probability	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)	(7a)
(1a)	1,000000						
(2a)	**0,847215**	1,000000					
(3a)	**0,155101**	0,465524	1,000000				
(4a)	**0,063522**	0,165784	**0,072327**	1,000000			
(5a)	**0,352906**	0,202463	**-0,062006**	-0,133955	1,000000		
(6a)	**0,364380**	0,266953	**0,050816**	**-0,078180**	0,061123	1,000000	
(7a)	**0,258603**	0,375401	**0,246203**	0,307027	0,239438	**-0,269150**	1,000000

Note: Bold denotes statistical significance at the 10% level. (1a), (2a), (3a), (4a), (5a), (6a) and (7a) represent ln(co$_2$pc), ln(rgdppcppp), ln(energy_efficiency), alternative_energy, coal_energy, indus and polity2, respectively.

Table 6B. Correlation Coefficients for LSO_2pc.

Correlation Probability	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)	(7b)
(1b)	1,000000						
(2b)	0,578088	1,000000					
(3b)	0,094578	0,456616	1,000000				
(4b)	-0,051491	0,181197	**0,075819**	1,000000			
(5b)	0,428931	0,207153	**-0,072442**	**-0,138794**	1,000000		
(6b)	-0,222631	-0,529880	**-0,278145**	-0,327406	**-0,272256**	1,000000	
(7b)	0,393648	0,284201	**0,059510**	-0,047335	0,095118	0,153405	1,000000

Note: Bold denotes statistical significance at the 10% level. (1a), (2a), (3a), (4a), (5a), (6a) and (7a) represent ln(so$_2$pc), ln(rgdppcppp), ln(energy_efficiency), alternative_energy, coal_energy, freedom and indus, respectively.

4.2. Test Results

4.2.1. CO$_2$

The first step in the analysis is to examine the stationarity of the variables, therefore, the ADF-Fisher and PP-Fisher unit root tests are applied. Table 7A and shows the panel unit root test results. Similar to the time series unit root test results, the majority of the variables are stationary; at the 5% significance level (except lnrgdppcppp, lnrgdppcppp^2, lnrgdppcppp^3 and lnenergy_efficiency that are in first difference I(1), which are plotted in Fig. 23). Therefore, it is no need to apply panel cointegration techniques in order to examine the existence of long-run cointegrated relationship among variables.

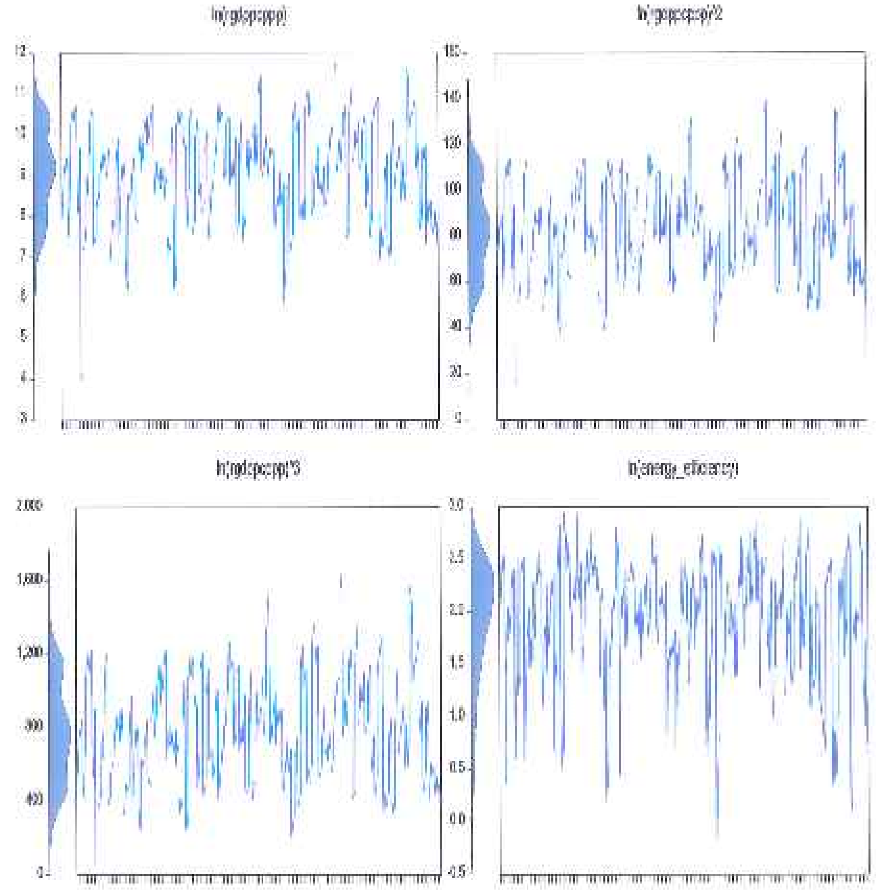


Fig. 23. Logarithms of Real GDP Per Capita, Squared Real GDP Per Capita, Cubic Real GDP Per Capita and Energy Efficiency, respectively.

Table 7A. ADF-Fisher and PP-Fisher Unit Root Test Analysis for LCO_2PC

Variables	**ADF-Fisher test at level**		**ADF-Fisher at 1st difference**		**PP-Fisher test at level**		**PP-Fisher at 1st difference**	
	T-stat	*P-value*	*T*-stat	*P-value*	*T*-stat	*P-value*	*T*-stat	*P-value*
LCO_2PC	593,219	0,0000			558,898	0,0000		
LGDPPCPPP	152,597	1,0000	902,963	0,0000	149,359	1,0000	1079,84	0,0000
$LGDPPC^2PPP^2$	141,654	1,0000	892,168	0,0000	142,868	1,0000	1144,82	0,0000
$LGDPPC^3PPP^3$	137,130	1,0000	883,008	0,0000	137,542	1,0000	1134,44	0,0000
LENERGY EFFICIENCY	213,252	0,8740	1349,09	0,0000	188,191	0,9925	1735,99	0,0000
ALTERNATIVE_ ENERGY	342,083	0,0000			359,566	0,0000		
COAL_ ENERGY	276,381	0,0000			410,357	0,0000		
INDUS	439,675	0,0000			341,549	0,0000		
POLITY2	289,469	0,0000			263,492	0,0000		

As the variables are observed to be stationary, the next step in the analysis is to examine the correlation between the dependent and independent variables by utilizing the fixed effects, random effects model and generalized method of moments (GMM) model. Table 8A reviews the results of the panel regressions for the fixed effects and random effects model. The Hausman test is performed to confirm whether the fixed effects or the random effects model is the optimal model for my panel regression. Because the Chi-square is significant at the 1%, 5% and %10 level for nations in the panel, the fixed effects model is the optimal model for the analysis. However, the problem with the fixed effects model is that it is weak in controlling heterogeneity and serial correlation. Hence, it is important to make the fixed effects model robust in terms of serial correlation and heterogeneity, which can be done by computing standard errors that are robust to serial correlation and heterogeneity (Al-mulali et al., 2014: 319).

Although the specification 1 and 2 of the fixed effects models is chosen over the random effects models, they show that there are neither the inverted U-shaped nor N-shaped curves for CO_2. More specifically, specification 1 merely shows the variable LRGDPPCPPP is negatively related to global warming caused by CO_2, failing to verify a quadratic relationship. In other words, it shows that there is a U-shaped relationship between income and global warming, with the turning point, $0,201078. In the same way, specification 1 of the random effects model shows that there is a U-shaped relationship between income and global warming, with the turning point, $0,206874. Specification 2 also fails to prove a cubic relationship. The estimated coefficient of GDP per capita is negative and statistically significant while the coefficient of the squared term is not, thereby, the economy experiences a monotonically decreasing pattern. Similarly, specification 2 of the random effects model shows an evidence of monotonically decreasing EKC. All in all, comparing the magnitude of the effects, the real GDP per capita is by far the most important determinants of global warming even not supporting the EKC hypothesis.

These results are deviated from the findings of several literatures on EKC, i.e., Holtz-Eakin and Selden (1995) have done probably the first study on EKC for CO_2 and found a monotonous straight line. They employed a quadratic model for a panel of 130 nations and obtained some support for an EKC of CO_2. On the other hand, their estimated turning point occurs at a very high level of per capita income ($35,428 in per capita 1986 dollars) for the 1995 study. Shafik (1994) investigated the effectiveness of EKC in relation to linear, quadratic and cubic models. His findings showed various relationships for CO_2 and no specific turning point was detected. In contrast, Agras and Chapman (1999) found a low amount of income per capita for turning point of CO_2 (only $13,630). Maradan and Vassiliev (2005) studied a number of nations with a wide variety of per capita GDP; his derived turning point was widely varied. He found a turning point for CO_2 at an average GDP per capita of $5,924. His minimum GDP per capita (expressed in PPP) for turning point was $325 and maximum was $17,508 in 1985 value (Miah et al. 2010: 4646).

In fact, most empirical results for CO_2 have showed an upward straight line with no turning point. Gangadharan and Valenzuela (2001) found an upward straight line for carbon pollution for a panel of 51 nations. Shafik and Bandyopadhyay (1992) found an upward straight line for a panel of 135 nations. Hill and Magnani (2002) have done the largest study on CO_2, with a panel data of 156 nations around the world. They showed no evidence of inverted U-shape EKC and also emissions monotonically increase with income per capita. Lindmark (2002) did not find any turning point for CO_2 in Sweden. With data for Australian income per capita and CO_2 emission, Friedl and Getzner (2003) found a turning point, but pollution tended to increase afterwards and did not follow any specific trend (Miah et al. 2010: 4646).

Both the specification 1 and 2 of the fixed effects and random effects model report that all variables turn out to be significant. With respect to those variables measuring economic conditions, the correlation of the industry share in GDP is as expected positive. While a higher share of electricity produced from coal negatively affects the environment, the availability of alternative energy sources reduces global warming. The variable measuring efficient manufacturing technology is significant and shows a negative coefficient for global warming proxy. The less energy is used to produce 1 unit of GDP, the more efficient is the production process and the less waste is generated. The result provides evidence that a "technology shock" improves environmental quality in general. That is, after a certain threshold of development, the environment seems to benefit. However, it should be regarded that reaching this point is not a self-fulfilling prophecy (Lamla, 2009: 141).

Also, the variable measuring governance conditions, polity2 has a negative effect on the quality of the air, which fits the common sense that democracy is no "panacea" for protecting the environment. Global warming develops slowly and over long periods of time, but elected governments may have shorter planning horizons to solve such a long-term environmental issue. The social costs of current economic behavior and political choices often materialize over the long term and burden future generations and politicians. In short, democracies may under-supply environmental protection relative to non-democratic regimes (Bernauer & Koubi, 2009: 1357).

Table 8A. OLS Estimated Results for LCO$_2$pc.

	Fixed Effects		Random Effects	
Variables	Model 1	Model 2	Model 1	Model 2
Δ(LGDPPCPPP)	-3,867229 (0,0000)[a]	-7,079166 (0,0406)	-3,974811 (0,0000)	-6,864954 (0,0469)
Δ(LGDPPC^{2}PPP^2)	0,201078 (0,0000)	0,580198 (0,1486)	0,206874 (0,0000)	0,547486 (0,1725)
Δ(LGDPPC^{3}PPP^3)		-0,014707 (0,3427)		-0,013196 (0,3942)
Δ(LENERGY_ EFFICIENCY)	-0,380490 (0,0000)	-0,378198 (0,0000)	-0,376706 (0,0000)	-0,374365 (0,0000)
ALTERNATIVE_ ENERGY	-0,005188 (0,0016)	-0,005323 (0,0013)	-0,004665 (0,0036)	-0,004744 (0,0031)
COAL_ENERGY	0,009924 (0,0000)	0,009953 (0,0000)	0,010288 (0,0000)	0,010337 (0,0000)
INDUS	0,011053 (0,0000)	0,011079 (0,0000)	0,011545 (0,0000)	0,011604 (0,0000)
POLITY2	0,011378 (0,0000)	0,011455 (0,0000)	0,011867 (0,0000)	0,011970 (0,0000)
Adjusted R^2	0,982076	0,982076	0,176865	0,176637
DW statistics	0,390607	0,391196	0,360731	0,359202
F-statistics	1004,796	996,7825	71,29229	62,40955
Hausman test			66,489263	83,821871

[a]Probability values are in parenthesis.

The easiest way to estimate a panel data model like Eq. (1) is to ignore any dynamic relationship between environmental quality and development. Thus, this thesis utilizes the system GMM method to estimate the dynamic model of EKC in Eq. (1). Replacing *ln(pollutant)* by $ln(co_2pc)$, the system GMM estimation results are presented in Table 9A. The panel data have the characteristics of medium time span but large cross-sectional dimensions and include the lagged explanatory variables.

In both model (1) and (2), the lag range of (2-4) means that the 2nd through the 4th order lag terms of the endogenous variables are included as instruments in the transformed difference equation whereas the first order lag terms are included in the level equation in the system GMM estimation. This probably results in stochastic disturbance terms relating to explanatory variables as well as the other explanatory variables may also be endogenous. Therefore, this thesis adopts the two-step GMM method to test the model. When it is used the GMM estimation method, it is also adopted Sargan test for reliability of the instrumental variable. If the test value is small, it is accepted that the null hypothesis that the instrumental variable is suitable. It is used both first-order and second-order serial correlations of first difference transformation equation to test AR(1) and AR(2) in order to decide whether random disturbance is serial correlation.

In model 1, it is firstly noted that the coefficient of A(LRGDPPCPPP) is negative and the coefficient of A(LRGDPPCPPP)^2 positive, both of which are highly significant, consistently across all estimations. Thus, these results lend robust support to the existence of a U-shaped EKC for emissions in the worldwide nations, suggesting that the CO_2 emissions initially fall and then rise after reaching with a turning point in economic growth/development, which contradicts the Hypothesis 1.

Far from being an academic concern, this debate is of great importance to national and international environmental policy. Policy implications are generally established depend upon the conventional wisdom that developing nations will automatically become cleaner as their economies grow. Thus, it is natural process for the poorest nations to become more polluted as they develop. However, the evidence for an inverted U is much less robust than previously thought, since the locations of the turning points and their very existence are sensitive both to slight variations in the data and to reasonable permutations of the econometric specification (Harbaugh et al., 2002: 541).

According to Dinda et al. (2000), a possible reason of the U-shaped pattern might be sought in the dynamics of the process of economic growth experienced by the nations concerned. For instance, economic development may strengthen the market mechanism as a result of which the economy may gradually shift from non-market to marketed energy sources that are less polluting. Or alternatively, thanks to the global technical progress the production techniques available to the nations all over the world are becoming more and more capital intensive and at the same time less polluting. This may suggest that, given the income level, the pollution level falls as the capital intensity of an economy rises. That is to say, it is not only the level of income but also the characteristics of an economy which together determine the rate of environmental degradation that an economy will experience as it moves along the trajectory of development.

According to Kaufmann et al. (1998), the U-shaped relation can be explained by changes in energy use that generally accompany economic development. As income rises, nations change the types of energy sources that they use for electricity generation. These shifts often move nations away from coal sources (both primary: hard coal and lignite-brown coal and derived fuels: patent fuel, coke oven coke, gas coke, coke oven gas, blast furnace gas) towards alternative (non-fossil) sources (hydropower, nuclear, geothermal, solar power, etc.) for the production of electricity. However, beyond turning point, CO_2 emissions may increase. This increase could be generated by increases in energy consumption that outweigh the effects of the ongoing shift towards energies with a "clean energy", is noncarbohydrate energy that does not produce carbon dioxide when generated, and an increase in the marginal costs of abating emissions.

In model 2, it is firstly noted that the coefficient of Δ(LRGDPPCPPP) is negative and the coefficient of Δ(LRGDPPCPPP)^2 positive, and the coefficient of Δ(LRGDPPCPPP)^3 negative, three of which are highly significant, consistently across all estimations. These results contrast with the Hypothesis 2 in that it is not found an N-shape curve. Rather, it is founded that the curve is an inverted-N shaped (and sometimes flattened inverse-S shaped) curve where the slope is mostly positive everywhere, except for the inflection point where the slope is zero. In this context, Gangadharan and Valenzuela (2001) partition the environmental pressure experience of nations into distinct three phases. During the first phase when per capita incomes are low, environmental pressure tends to increase but a decreasing rate. During the second phase when per capita incomes are higher, environmental pressure levels appear controlled and no increases are observed. Finally, the third phase appears at extremely high incomes when emissions increase again and escalate rapidly. This implies that the effect of income on the environment is more significant at the extreme ends of the income scale.

Secondly, the coefficients of the lagged dependent variable are positive and highly significant in these regressions, indicating that CO_2 emissions are positively serially correlated and hence justifying my study of a dynamic EKC specification. Moreover, consistent with previous EKC studies, the sign of energy efficiency and alternative (non-fossil) sources of electricity production is negative and highly significant; the share of the industry sector in the economy and dependence on coal sources for the production of electricity is positive and highly significant in both regressions.

Furthermore, the sign of the difference between the sub-indexes for democracy and autocracy is as expected positive in both regressions. In this regard, these empirical results fit previous EKC studies displaying democracy may not improve the environmental quality or may even worsen it. The arguments proposed in these studies are as contrasting as compelling. Li and Reuveny (2006) derived four causal mechanisms as to why democracy might worsen environmental performance comparing to autocratic nations. The first causal mechanism is that (unlimited) freedom in a democracy causes unchecked behavior by overharvesting individuals, according to Hardin (1968); the second, autocracies can impose stricter regulations on population growth; the third, in democracies leaders will enact election-winning policies and therefore tend to promote policies supporting the employment of voters rather than the environment; and finally, democracies are often market economies where corporate interests have more influence than environmentalists. By the same token, Bernauer and Koubi (2009) confirmed that mature democracies are influenced by special interest groups, which have little or no incentive to compromise their interests for the environment, which in turn might curtail the positive effect of democracy on the provision of public goods (Povitkina et al., 2015: 26).

Table 9A. GMM Estimated Results for LCO$_2$pc.

GMM SYSTEM	Model 1	Model 2
Variables		
$(LCO_2PC)_{it-1}$	0,731618 (0,0000)	0,743789 (0,0000)
Δ(LGDPPCPPP)	-0,694641 (0,0018)	-3,170303 (0,0171)
Δ(LGDPPC^{2}PPP^2)	0,077681 (0,0000)	0,381702 (0,0264)
Δ(LGDPPC^{3}PPP^3)		-0,012170 (0,0907)
Δ(LENERGY_ EFFICIENCY)	-0,680605 (0,0000)	-0,698832 (0,0000)
ALTERNATIVE_ ENERGY	-0,006360 (0,0000)	-0,006176 (0,0000)
COAL_ENERGY	0,003530 (0,0000)	0,003391 (0,0001)
INDUS	0,005539 (0,0000)	0,005672 (0,0000)
POLITY2	0,006674 (0,0000)	0,007255 (0,0000)
AR(1) test	-4,943817 (0,0000)	-4,925884 (0,0000)
AR(2) test	-0,712415 (0,4762)	-0,705415 (0,4806)
Sargan test *p*-value	0,522769	0,508982

Note: The tests of significance are conducted with $\alpha = 0,10$

Based on the results of this thesis, the following policy recommendations are put forward to further mitigate CO_2 emissions in the worldwide nations.

Overall, rapid economic growth with great CO_2 emissions in the worldwide nations will not last a long time. Given that those nations are going away from the second upward phase of "U" curve to the third downward phase of the inverted "N" curve (see Fig. 24 and 25). In the second phase of the development, the frequent CO_2 pollution threatens on the survival of human beings. With reference to this finding, policymakers need to abandon the development idea of governance after pollution which has destroyed the ecological environment heavily. That is, it is imperative that both of the national and international governments should adopt and implement policies in order to mitigate environmental degradation rather than favor the EKC hypothesis. In this way, economic growth will eventually improve the environmental quality in the third phase of the development.

From the global perspective, the coefficients of the lagged dependent variable, the share of the industry sector in the economy and dependence on coal sources for the production of electricity as well as the difference between the sub-indexes for democracy and autocracy increase global warming, while the sign of alternative (non-fossil) sources of electricity production and energy efficiency dampen global warming significantly. Diagrammatic representations of the estimated emissions-income with energy efficiency, alternative energy, coal energy, industry and polity2 equations are presented in Table 1C, Table 2C, Table 3C, Table 4C and Table 5C, respectively. Consequently, both national and international governments should make overall plans for cutting emissions regarding the industrial layout and make targeted carbon-reduction policies. For example, they should increase the share of non-fossil energy and promote more eco-friendly industrial process, including the installation of de-carbonization systems and technological developments in the field of wind power, hydropower, solar PV, nuclear and other renew energy power facilities.

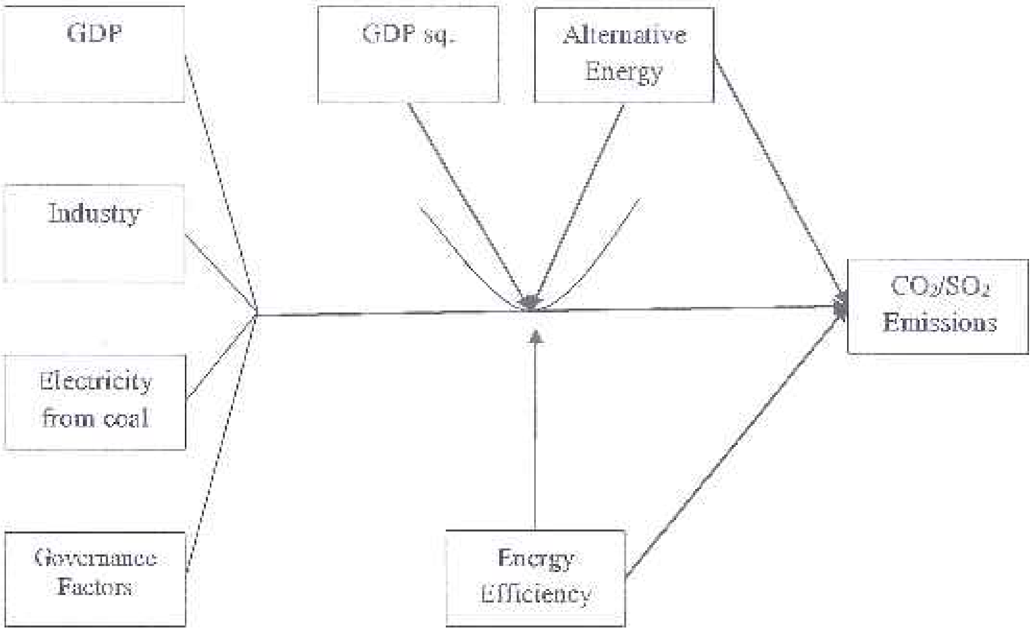


Fig. 24. Conceptual Model for U-Shaped Trajectory [Source: Own elaboration based on environmental literature].

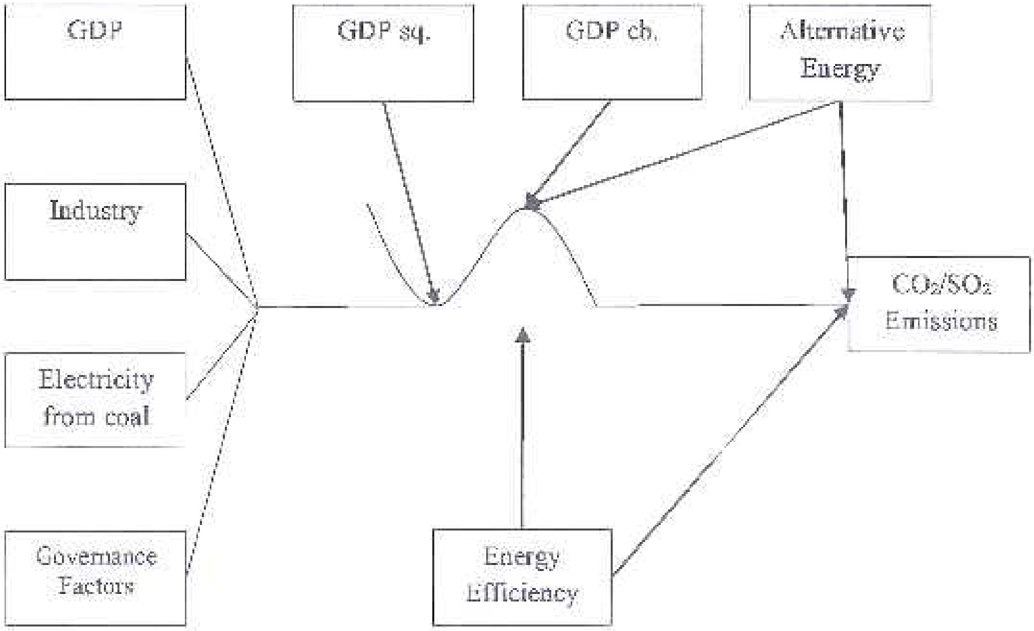


Fig. 25. Conceptual Model for Inverted N-Shaped Trajectory [Source: Own elaboration based on environmental literature].

4.2.2. SO_2

The first step in the analysis is to examine the stationarity of the variables, therefore, the ADF-Fisher and PP-Fisher unit root tests are applied. Table 7B and shows the panel unit root test results. Similar to the time series unit root test results, the majority of the variables are stationary; at the 5% significance level (except lnrgdppcppp, lnrgdppcppp^2, lnrgdppcppp^3 and lnenergy_efficiency that are in first difference I(1) which are plotted in Fig. 26). Therefore, it is no need to apply panel cointegration techniques in order to examine the existence of long-run cointegrated relationship among variables.

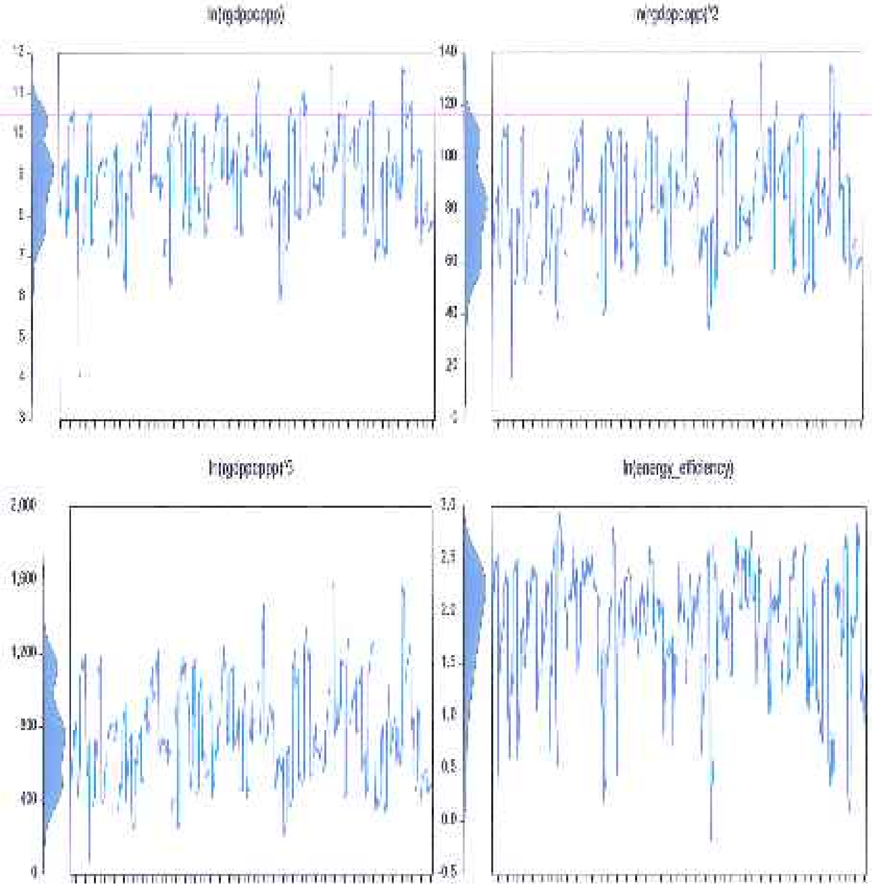


Fig. 26. Logarithms of Real GDP Per Capita, Squared Real GDP Per Capita, Cubic Real GDP Per Capita and Energy Efficiency, respectively.

Table 7B. ADF-Fisher and PP-Fisher Unit Root Test Analysis for LSO_2PC.

Variables	**ADF-Fisher test at level**		**ADF-Fisher at 1st difference**		**PP-Fisher test at level**		**PP-Fisher at 1st difference**	
	T-stat	*P-value*	*T*-stat	*P-value*	*T*-stat	*P-value*	*T*-stat	*P-value*
LSO_2PC	307,376	0,0012			405,751	0,0000		
LGDPPCPPP	173,073	0,9992	676,809	0,0000	171,192	0,9995	744,485	0,0000
$LGDPPC^2PPP^2$	168,322	0,9997	671,328	0,0000	165,538	0,9998	739,285	0,0000
$LGDPPC^3PPP^3$	163,944	0,9999	666,162	0,0000	163,653	0,9999	734,336	0,0000
LENERGY_ EFFICIENCY	217,539	0,8001	1002,86	0,0000	236,969	0,4700	1157,83	0,0000
ALTERNATIVE_ ENERGY	311,274	0,0000			335,617	0,0000		
COAL_ ENERGY	218,263	0,0000			173,981	0,0060		
FREEDOM	329,685	0,0000			307,234	0,0000		
INDUS	300,307	0,0029			332,854	0,0000		

As the variables are observed to be stationary, the next step in the analysis is to examine the correlation between the dependent and independent variables by utilizing the fixed effects, random effects model and generalized method of moments (GMM) model. Table 8B reviews the results of the panel regressions for the fixed effects and random effects model. The Hausman test is performed to confirm whether the fixed effects or the random effects model is the optimal model for my panel regression. Because the Chi-square is significant at the 1%, 5% and %10 level for nations in the panel, the fixed effects model is the optimal model for the analysis. However, the problem with the fixed effects model is that it is weak in controlling heterogeneity and serial correlation. Hence, it is important to make the fixed effects model robust in terms of serial correlation and heterogeneity, which can be done by computing standard errors that are robust to serial correlation and heterogeneity (Al-mulali et al., 2014: 319).

Although the specification 1 and 2 of the fixed effects models is chosen over the random effects models, they show that there is no evidence of EKC hypothesis. Similarly, the specification 1 and 2 of the random effects models showed the same results. These empirical results imply that the estimated coefficient of GDP per capita is negative and statistically insignificant and so is the coefficient of the squared term; as a result, the economy experiences no specific pattern of EKC. In addition, both the specification 1 and 2 of the fixed effects and random effects model report that a minority of the variables turn out to be significant. With respect to those variables measuring economic conditions, the correlation of the industry share in GDP is as expected positive. While a higher share of electricity produced from coal negatively affects the environment, the availability of alternative energy sources reduces air pollution.

These results are deviated from the findings of several literatures on EKC, i.e., Seldon and Song (1994) argued that SO_2-generated air pollution is alleviated around the turning point of $8,709, and similarly Kunnas and Myllytaus (2007) estimated the turning point is around $10,000 (Park & Lee, 2011: 5845). Roca et al. (2001) analyzed the EKC hypothesis for Spain using six air pollutants as indicators of environmental quality, and their findings confirmed that hypothesis for just sulfur emissions. Similarly, Cole et al. (1997) found evidence that only local atmospheric pollutants are compatible with the hypothesis. Stern and Common (2001) used a global sample and a separate sample of high-income OECD nations in order to test the hypothesis for sulfur emissions, and their findings supported existence of the hypothesis in those nations. Stern (2006) used panel data of 82 nations for 1971-1990 to support the EKC existence for sulfur emissions. However, Harbaugh et al. (2002) argued that existence of an inverted U-shaped curve pattern is very sensitive to changes in nations, cities and periods sampled. Fodha and Zaghdoud (2010) showed an inverted U-shaped curve relationship between sulfur emissions and economic growth. Fosten et al. (2012) discovered existence of the EKC hypothesis for sulfur emissions with respect to economic growth, based on a long-term dataset from 1830 (Wang et al., 2016: 1183).

Table 8B. OLS Estimated Results for LSO_2pc.

	Fixed Effects		Random Effects	
Variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Δ(LGDPPCPPP)	-0,288799 (0,8397)[a]	-4,825131 (0,4600)	-0,927265 (0,5144)	-3,756320 (0,5643)
$\Delta(LGDPPC^2PPP^2)$	-0,042755 (0,6110)	0,508802 (0,5138)	-0,008273 (0,9213)	0,335602 (0,6659)
$\Delta(LGDPPC^3PPP^3)$		-0,022086 (0,4765)		-0,013767 (0,6562)
Δ(LENERGY_ EFFICIENCY)	0,059283 (0,6712)	0,063251 (0,6510)	0,068772 (0,6221)	0,071269 (0,6098)
ALTERNATIVE_ ENERGY	-0,021621 (0,0000)	-0,021865 (0,0000)	-0,017682 (0,0000)	-0,017812 (0,0000)
COAL_ENERGY	0,021803 (0,0000)	0,021780 (0,0000)	0,021283 (0,0000)	0,021270 (0,0000)
FREEDOM	0,004702 (0,5406)	0,004592 (0,5502)	-0,001407 (0,8484)	-0,001494 (0,8393)
INDUS	0,012337 (0,0000)	0,012379 (0,0000)	0,014211 (0,0000)	0,014234 (0,0000)
Adjusted R^2	0,943697	0,943678	0,189222	0,188807
DW statistics	0,329398	0,330188	0,301902	0,302271
F-statistics	218,4885	216,6727	54,64494	47,81228
Hausman test			44,140398	46,016490

[a] Probability values are in parenthesis.

The easiest way to estimate a panel data model like Eq. (1) is to ignore any dynamic relationship between environmental quality and development. Thus, this thesis utilizes the system GMM method to estimate the dynamic model of EKC in Eq. (1). Replacing *ln(pollutant)* by *ln*(so_2pc), the system GMM estimation results are presented in Table 9B. The panel data have the characteristics of medium time span but large cross-sectional dimensions and include the lagged explanatory variables.

In both model (1) and (2), the lag range of (2-4) means that the 2nd through the 4th order lag terms of the endogenous variables are included as instruments in the transformed difference equation whereas the first order lag terms are included in the level equation in the system GMM estimation. This probably result in stochastic disturbance terms relating to explanatory variables as well as the other explanatory variables may also be endogenous. Therefore, this thesis adopts the two-step GMM method to test the model. When it is used the GMM estimation method, it is also adopted Sargan test for reliability of the instrumental variable. If the test value is small, it is accepted that the null hypothesis that the instrumental variable is suitable. It is used both first-order and second-order serial correlations of first difference transformation equation to test AR(1) and AR(2) in order to decide whether random disturbance is serial correlation.

In the case of air pollution, In model 1, it is firstly noted that the coefficient of Δ(LRGDPPCPPP) is positive and the coefficient of Δ(LRGDPPCPPP)^2 negative, both of which are highly significant, consistently across all estimations. These results thus lend robust support to the existence of an inverted U-shaped EKC for emissions in the worldwide nations, implying that the SO_2 emissions initially increase and then decrease after reaching with a turning point in economic development. In model 2, it is noted that the coefficient of Δ(LRGDPPCPPP) is positive and the coefficient of Δ(LRGDPPCPPP)^2 negative, but the coefficient of Δ(LRGDPPCPPP)^3 positive, only top two of which are highly significant, consistently across all estimations. These results contrast with the Hypothesis 2 in that it is not found an N-shape curve. Rather, it is found that the curve is an inverted U-shaped as in the model 1.

These empirical results fit the early EKC studies confirming local pollutants are more likely to indicate an inverted U-shape relation with income, while global effects such as carbon dioxide do not. In particular, this scenario fits environmental economics theory: local effects are internalized within a single economy or region and are likely to cause environmental policies to correct the externalities on pollutees before such policies are applied to globally externalized problems (Stern, 2004: 1423).

Robalino-López et al. (2014) explain the reason for this behavior with the help of distinct three phases. During the first phase when GDP reaches a certain threshold the economy moves into a different regime, where the rate of emissions with respect to income can be reduced with respect to the initial regime. In this phase, as in the developing nations, emissions scale with the *size of the economy*, since the industries are relatively rudimentary, unproductive and polluting. During the second phase, the effect of the economic growth on environmental degradation is mitigated through the *structure and composition effect*, since the economy growth stimulates structural changes. In particular, this phase takes place as an agricultural based economy shifts into a manufacturing services based economy. Finally, the third phase arises when *nations invest intensively in research and development and the dirty and obsolete technologies are replaced by clean ones*. At this point the pollution tends to decrease as a function of the GDP.

Secondly, the coefficients of the lagged dependent variable are positive and highly significant in these regressions, indicating that SO_2 emissions are positively serially correlated and hence justifying my study of a dynamic EKC specification. Moreover, consistent with previous EKC studies, the sign of energy efficiency and alternative (non-fossil) sources of electricity production is negative and highly significant; the share of the industry sector in the economy and dependence on coal sources for the production of electricity is positive and highly significant in both regressions.

Furthermore, the sign of the sum of the Freedom House Political Rights and Civil Liberties Indices is negative in both regressions. These results contrast with the Hypothesis 6 in that it is not found a positive correlation between freedom and air pollution. Rather, it is found that freedom has a positive effect on air quality, in contrast with the results of CO_2. In this regard, these empirical results fit previous EKC studies confirming democratization makes citizens better informed and enabled to protest.

The arguments proposed in these studies are as contrasting as compelling. In this context, Li and Reuveny (2006) derived five causal mechanisms as to why democracy might improve environmental performance comparing to autocratic nations. The first causal mechanism assumes that *political rights and freedom* often stimulate public awareness as well as environmental action; the second, systems with *electoral accountability* are more responsive to citizens' environmental concerns and the influence from environmentalists on policy; the third, thanks to the dominating principles of *rule of law*, *aversion to war* and *respect for life*, democracies tend to produce less environmental destruction than autocracies; the fourth, *the elite in an autocratic society* is less pro-environmental than the public mass; finally, relatively *short time horizons* of autocratic leaders tend to promote overexploitation. Similarly, autocracies are thought to implement less stringent environmental policies, since governmental leaders prefer to avoid payments of the costs of tight rules themselves. Thus, they tend to prioritize economic development over environmental protection and are argued to allow supporters of the governments to overexploit ecosystems in order to pay off the support (Povitkina et al., 2015: 26).

Table 9B. GMM Estimated Results for LSO_2pc.

GMM SYSTEM Variables	Model 1	Model 2
$(LSO_2PC)_{t-1}$	0,831793 (0,0000)	0,828447 (0,0000)
Δ(LGDPPCPPP)	3,527414 (0,0000)	6,861775 (0,0050)
$\Delta(LGDPPC^2PPP^2)$	-0,167812 (0,0000)	-0,567168 (0,0481)
$\Delta(LGDPPC^3PPP^3)$		0,015665 (0,1672)
Δ(LENERGY_ EFFICIENCY)	-0,629440 (0,0000)	-0,627056 (0,0000)
ALTERNATIVE ENERGY	-0,005551 (0,0000)	-0,005367 (0,0000)
COAL ENERGY	0,004768 (0,0000)	0,004865 (0,0000)
FREEDOM	-0,008815 (0,0135)	-0,009249 (0,0063)
INDUS	0,001151 (0,0074)	0,001110 (0,0099)
AR(1) test	-5,218805 (0,0000)	-5,187754 (0,0000)
AR(2) test	-1,553336 (0,1203)	-1,577511 (0,1147)
Sargan test *p*-value	0,493473	0,514327

Note: The tests of significance are conducted with $\alpha = 0,10$

Based on the results of this thesis, the following policy recommendations are put forward to further mitigate SO_2 emissions in the worldwide nations.

Overall, rapid economic growth with great SO_2 emissions in the worldwide nations will not last a long time. Given that those nations are going away from the first upward phase to the second downward phase of the inverted "U" curve (see fig. 17). In the first phase of the development, the frequent SO_2 pollution threatens on the survival of human beings, but in the second phase of the development SO_2 pollution tends to decay. With reference to this finding, policymakers are said to be employing a strategy of "pollute first, clean up later". In other words, these results provide strong evidence for the conventional Environmental Kuznets Curve (EKC), i.e., the notion that air pollution increases at initial levels of economic development and reduces after a turning point of advanced economic development.

From the global perspective, the coefficients of the lagged dependent variable, the share of the industry sector in the economy and dependence on coal sources for the production of electricity increase air pollution, while the sign of the sum of the Freedom House Political Rights and Civil Liberties Indices, alternative (non-fossil) sources of electricity production as well as energy efficiency dampen air pollution significantly. Diagrammatic representations of the estimated emissions-income with energy efficiency, alternative energy, coal energy, industry and freedom equations are presented in Table 1D, Table 2D, Table 3D, Table 4D and Table 5D, respectively. Thus, both national and international governments should make overall plans for cutting emissions regarding the industrial layout and make targeted sulfur-reduction policies. For instance, they should increase the share of non-fossil energy and promote more eco-friendly industrial process, including the installation of desulfurization systems and technological developments in the field of wind power, hydropower, solar PV, nuclear and other renew energy power facilities.

4.3. Discussions

The major weakness in the previous literature on CO_2 and SO_2 emissions and the Environmental Kuznets curve (EKC) hypothesis is that most studies reflect only a small portion of total environmental degradation (Al-mulali et al., 2014: 319) at least three reasons. Firstly, empirical findings are estimated from conventional panel models do not capture the dynamic process well enough to evaluate the argument that economic growth is "de-linked" from environmental degradation in individual nations (De Bruyn et al., 1998: 173). Secondly, there is no reason to assume that the same emission-income relationship ("one-size fits all" EKC) will be experienced by all nations given the great diversity of institutions, political structures, geography, culture as well as climate characteristics that exist across nations (Cole, 2005: 5). Thirdly, EKC may have a different shape and scenario for global (CO_2) versus local (SO_2) pollutants. In the case of local pollutants, effects are also local and can be internalized within a single economy or region, but in the case of global pollutants, effects are global and cannot be internalized by a single economy (Miah et al. 2010: 4646).

All in all, the empirical results are found in this thesis underscore that the econometric technique used is very important in the extraction of turning points and the associated policy implications. Thus, if it is allowed for a dynamic adjustment in this model then it is more likely to derive quite different results (Halkos, 2003: 598). Estimating dynamic panel models indicate that polity2 has a direct positive effect on the CO_2 emissions, while freedom has a direct negative effect on the SO_2 emissions. Despite the differences between CO_2 and SO_2 emissions due to the capability of democracy, both emissions may decline over time, probably due to reaching low carbon and sulfur energy-industrial revolution and development. Also, nations that invest more in energy efficiency and alternative (non-fossil) sources of electricity production, industrialization tends to be more environmentally benign in the long run.

This thesis is concerned with the debated issue of whether democracy is favorable or adverse for the environment. Estimated results for SO_2 indicate that an alternative measure of democracy (freedom) raises the likelihood of successful collective action and sustainable development while estimated results for CO_2 hold that democratic systems (polity2) tend to fall prey the public's unwillingness to adopt and implement environmentally sound policies. According to the latter perspective, democracy either needs to be exchanged for less democratic political systems with unbounded capacity to reorient society away from environmentally unsustainable paths or be guided by more deliberative and participatory ideals. Those instead holding that democracy is "panacea" for the environment argue that democracy is an efficient coordination mechanism and that democratic values and procedures, like freedom of speech and information, raise the likelihood of sustainable development (Povitkina et al., 2015: 26).

What these results show is hence that the effect of democracy differs significantly depending on the type of individual emissions (see Table 5C and Table 5D in Appendix). This lends support to the argument that even though democracy might have an *intrinsic* value, it does not necessarily or automatically solve any type of environmental degradation. For some environmental issues, it is difficult to model cause and effect, the problem definition may change over time, and there may not be consensus about the policy goal. Whether effects are local vs. global (or even something in between) typically is a function of physical factors which are not amenable to change, but would influence the optimal design of policies. On one hand, global pollutants such as CO_2 imply that location of emissions or abatement does not influence atmospheric concentrations, thus policies could encourage least cost abatement regardless of location. On the other hand, local pollutants such as SO_2 are particularly easily observable ones, are more likely to follow the environmental Kuznets curve due to stakeholder pressure on governments, implying that they are a less wicked problem and hence would have lower enactment costs than problems requiring international agreements (McCann, 2013: 253-255).

CHAPTER 5

CONCLUSIONS & POLICY IMPLICATIONS

The relationship between economic development and environmental quality has been extensively investigated since the 1990s. The shape of this relationship has implications for the establishment of a proper joint economic and environmental policy: depending on whether there is a negative or a positive effect of economic development on environment, policy suggestions will differ (Azomahou et al., 2006: 1347). This vivid debate revolves around the existence of an *Environmental Kuznets Curve* (EKC) hypothesis, which is a statistical artifact that summarizes aspects of collective human behavior in terms of environmental degradation and sustainability development (Menegaki & Tsagarakis, 2015: 1469).

The basic objective of this thesis is to re-examine the EKC hypothesis empirically using a large sample of nations in a panel framework on both global warming and air pollution indicators, i.e., CO_2 and SO_2, respectively. This thesis applies to 119 worldwide nations from 1990 to 2011 for CO_2 and 118 worldwide nations from 1990 to 2005 for SO_2. It utilizes at first OLS (i.e., fixed/random effects models) which is traditional technique for testing EKC. But, the OLS level estimator is biased. and thus it uses GMM-SYS estimators that can use information from both difference and level equations, and that work well for panel data with large sample size and medium time span estimators. Corresponding to different weight matrixes, two-step GMM is also preferred (Ren et al., 2014: 129). All in all, it is noteworthy that the calculated Kuznets-type trajectory for the panel framework and two different emissions based on GMM-SYS estimates are much more reliable than those from statistic panel data estimates which simply ignore the characteristic of dynamics and suffer from potential endogeneity.

The estimated coefficients of both the global warming's and air pollution's determinants (causes) indicate that real GDP per capita, energy efficiency, industry, coal and alternative (non-fossil) sources of electricity production and governance factors (i.e., polity2 and freedom) are the primary determinants. Traditional EKC hypothesis postulates that technological effect is one of the factors which derive the declining part of EKC throughout the entire period of economic development, that the shift of the scale effect, structural effect and technological effect affect the direction of EKC (Yin et al., 2015: 106). This thesis got the similar result that energy efficiency, which intends to proxy for the level of efficiency in the production process, decreases emissions in both the increasing and decreasing stages of both CO_2 and SO_2 Kuznets curve. Nevertheless, the results indicate that there are different EKC scenarios with respect to the type of the pollutants (global or local). Thus, policies should be designed and implemented based on the analysis of characteristics of global and local pollutants.

More specifically, in the case of global warming, it has been observed a U-shaped relationship between per capita CO_2 emissions and per capita real income, which contradicts the Hypothesis 1, is that Emissions of CO_2 will have a statistically significant relationship with real per capita GDP, showing an inverted U-shaped curve, ceteris paribus. The notion that global warming decreases at initial levels of economic development, but increases after a turning point of advanced economic development. In addition to this empirical result, it has been observed an inverted-N relationship between per capita CO_2 emissions and per capita real income, which contradicts the Hypothesis 2, is that emissions of CO_2 will have a statistically significant relationship with real per capita GDP, showing an N-shaped curve, ceteris paribus. The notion that CO_2 emissions at first follow a U-shaped pattern, after the last turning point of advanced economic development the CO_2 curve is flatter and less variable. While a higher efficiency in energy consumption and a larger share of alternative (non-fossil) sources of electricity production dampen global warming significantly, a larger share of the industry sector in the economy, dependence on coal sources for the production of electricity and the difference between the sub-indexes for democracy and autocracy increase global warming.

From a broad review of the literature, there are five causal mechanisms as to why democracy might worsen environmental performance comparing to autocracy. The first, (unrestricted) freedom in a democracy generate unchecked behavior by overharvesting individuals; the second, autocracies can impose stricter regulations on population growth; the third, in democracies leaders will enact election-winning policies and thus tend to promote policies supporting the employment of voters rather than the environment; the fourth, democracies are characterized as market economies where corporate interests have more influence than environmentalists; and finally, mature democracies are affected by special interest groups, which have little or no incentive to compromise their interests for the environment, which in turn might diminish the positive effect of democracy on the provision of public goods (Povitkina et al., 2015: 26).

In the case of air pollution, it has been observed an inverted-U relationship between per capita SO_2 emissions and per capita real income, which confirms the Hypothesis 1, is that emission of SO_2 will have a statistically significant relationship with real per capita GDP, showing an inverted U-shaped curve, ceteris paribus. The notion that air pollution increases at initial levels of economic development and reduces after a turning point of advanced economic development. In addition to this empirical result, it is also failed to prove a complete cubic relationship, although it reports the possibility of existence of an N-shaped curve, showing only the variables Δ(LRGDPPCPPP) and Δ(LRGDPPCPPP)^2 are statistically significant. While a higher efficiency in energy consumption and a larger share of alternative (non-fossil) sources of electricity production as well as the sum of the Freedom House political rights and civil liberties indices dampen air pollution significantly, a larger share of the industry sector in the economy, dependence on coal sources for the production of electricity increase air pollution.

From a broad review of the literature, there are six causal mechanisms as to why democracy might improve environmental performance comparing to autocracy. The first, *political rights and freedom* generate public awareness and environmental action; the second, systems with *electoral accountability* are more responsive to citizens' environmental concerns as well as the influence from environmentalists on policy; the third, democracies tend to produce less environmental destruction than autocracies because of the dominating principles of *rule of law*, *aversion to war* and *respect for life*; the fourth, *the elite in an autocratic society* is less pro-environmental than the public mass, the fifth, relatively *short time horizons* of autocratic leaders tend to promote overexploitation; finally, autocracies are assumed to adopt and implement less stringent environmental policies, since governmental leaders prefer to avoid payments of the costs of tight rules themselves (Povitkina et al., 2015: 26).

A relevant question is what governments, international bodies and non-governmental organizations (NGOs) can do using this EKC as a "statistical artifact" or, what type o recommendations can be given for economic/ecological policy. Even though its shape and origins have been questioned, EKC hypothesis provides a pile of information which better explains the relationship between an economy and the environment: as such it has significance for attempts to discover problems affecting the development of a low-carbon and –sulfur economy. In this regard, policy-makers and international environmental organizations may use this statistical artifact to monitor how the quality of the environment in a given nation varies over time or to evaluate a nation's efforts to improve environmental standards. Thus, this statistical artifact can also help those organizations to identify the most important determinants (causes) contributing to variations in global warming and air pollution. Knowing them allows formulating targets that should be met in the future to improve the quality of the air and the environment.

Policy implications in this thesis can be summarized as follows. First, the relationship between economic development and environmental quality is more complex than that hypothesized by the EKC model. Environmental scenarios are dynamic and subject to changing conditions resulted from pollution impacts (Diao et al., 2009: 547). According to the empirical findings, the slope and form of the EKC take various shapes (i.e., U, inverted-U, and inverted-N) depending on the type of the pollutants. More specifically, for global pollutants (CO_2), the results obtained are mixed. While the results for the quadratic model confirm a U-shape, with the turning point, $0,077681, the results for the cubic model confirm an inverted N-shape hypothesis, with the turning point ranging from $0,381702 to -$0,012170. For local pollutants (SO_2), both quadratic and cubic models confirm a "conventional inverted U-shaped EKC", with the turning points estimated, ranging from $-0,167812 to $-0,567168, respectively. All in all, the turning point levels of income established for the two indicators of environmental quality are generally low, when compared to evidence from existing studies. As for the internationally comparatively low turning points established for both environmental indicators, it should be pointed out that due to improvements in energy efficiency, the process of indusrial activities including nuclear and alternative energy sources of electricity production, both CO_2 and SO_2 emissions might flatten faster than expected.

Policy prescription for alleviating some of the forms of environmental degradation considered in this thesis suggest that rising incomes per capita alone are not all that is required in order to improve environmental quality. In this framework, environmental policies should take into account the characteristics and differences of global and local pollutants. That is to say, environmental and energy policies need to be 'customized' for each pollutant, rather to be standardized. Particularly, it should be recognized that the global problems whose direct sources are untraceable and transboundary, in contrast to the local (or simply traditional) problems derived from the traceable and immobile pollutants. In other words, environmental policies must be formulated concerning various features of global and local pollutants such as its origin, mobility, manageability, and so on (Park & Lee, 2011: 5847-5848).

The case of local pollutants such as SO_2 emissions, are one variable for which there is evidence that there is an inverted U-shape EKC. Particularly, simultaneity issues should be less essential than they might be for CO_2 emissions. In principle, sulfur, which cause direct harm to our health, but are discharged as a side product in industrial production and the burning of diesel fuel as well as heating with fossil fuels, it can be removed using 'end of pipe' technologies and substitution away from coal or high-sulfur coal is far easier than substitution away from fossil fuels in general. Also, changes in sulfur emissions are less likely to drive GDP growth than are changes in CO_2 emissions (Stern & Common, 2001: 163-164).

In contrast, the case of global pollutants such as CO_2 emissions is rather special. They cause no direct harm to our health, but are discharged as a by-product of other pollutants; it is hard to achieve low-carbon technology, due to the existence of the dual-influence of technology: it is difficult to devise the real influence of widely-defined technologies, even if those devoted to environmental remediation, on CO_2 emissions (Yin et al., 2015: 100). The different policy approach toward local, as opposed to global, emissions should be clear. Protection of a global common requires policies aimed at sustaining a global agreement, for which free riding behavior is a possible outcome (Galeotti & Lanza, 2005: 1380).

Second, nations that endeavor to improve their environmental quality should invest more in alternative, in particular green technologies of energy production, which is proven to be the most powerful predictor of global warming and air pollution (Buehn & Farzanegan, 2013: 112). For instance, nuclear energy is accepted as a low-carbon transitional energy, which contributes to stabilize the CO_2 level in the atmosphere, and thus decreases the climate change and global warming as well as air pollution. In particular, uranium is the source of the nuclear power, which is still available worldwide, and also it is not forecasted to deplete promptly like fossil fuels (AlFarra & Abu-Hijleh, 2012: 272).

Another vital contributor to eliminating both the CO_2 and SO_2 emissions is the renewable energy sources (solar, wind, biomass, geothermal energies), although most of these sources are still immature and under development yet. Moreover, renewable power has no self-sufficient coverage towards the ever-increasing energy demand, which is directly proportional to the increased population. In contrast, nuclear energy, as an already mature technology, is capable to fill-in part of the transition gap from fossil fuel till getting a fully mature renewable energy. That is why the electricity generation from nuclear power is included as a major component of the most nations in the world as a long term energy strategy (AlFarra & Abu-Hijleh, 2012: 272-273).

Third, nations that seek low carbon and sulfur development utilize only energy resources which cause no environmental effects or release no emissions to the environment. Nevertheless, since all energy resources cause some environmental effects, some of the concerns considering the limitations imposed on low carbon and sulfur development by emissions can be overcome through increased efficiency. Clearly, a strong relation exists between efficiency and environmental effects since, for the same services or products, less resource utilization, and thus emissions are normally related to increased efficiency (Dincer, 2000: 171; Dincer & Rosen, 2004: 10).

Most efficiency improvements generate direct environmental benefits at least two ways (Dincer & Rosen, 2004: 10): The former, improved energy efficiency reduces costly and inefficient energy subsidies that may help to decrease the energy intensity of production processes and their negative externalities on global warming and air pollution (Buehn & Farzanegan, 2013: 112). The latter, consideration of the entire life cycle for energy resources as well as technologies suggests that improved efficiency decreases environmental degradation during most stages of the life cycle (Dincer & Rosen, 2004: 10). These strategies might be particularly promising in oil rich economies in the Middle East, as 6 out of the top 10 nations with the highest energy subsidies are from the Middle East region (Buehn & Farzanegan, 2013: 112).

From this mixed evidence about the relationship of economic growth and environmental quality, it might be drawn some conclusions and points require elaboration for future research. The first and most obvious is that instead single policy which can reduce emission levels with rising economic growth; there are various transitional mechanisms in an economy's growth process that might lead to environmental improvement. Since environmental degradation in terms of global warming and air pollution which is a multifaceted problem and different stages of environmental damage have some definite relations with economic growth. Thus, it can be explained in multidimensional ways or in terms of multidimensional issues (Dinda, 2004: 454). As nations enjoy higher energy efficiency and alternative (non-fossil) sources of electricity production, the process of industrialization tends to be more environmentally benign in the long run although governance factors (i.e., polity2 and freedom) changes depend upon the type of pollutants (global or local), since each pollutant has its own particularities that should be counted for and not bypassed. These results provide strong support to the low carbon and sulfur energy-industrial revolution and development argument.

In spite of the valuable implications for literature and practice mentioned above, it is believed that the present study would have more significant contributions, if the dataset includes the data in the 1780s. Since this time marks the beginning of immense rises in human population and carbon emissions as well as atmospheric CO_2 levels, the so-called 'great acceleration'. This also anchors the "Anthropocene" on the first measurements of atmospheric CO_2, confirming the maximum level of around 280 ppm recognized from ice cores to be typical for the centuries preceding the Anthropocene (Foley et al., 2013: 83). Thus, future study would be recommended to go over the long history of global warming with the enlarged dataset of world. In addition, it would be better to pay close attention to variables that may have an indirect influence over air pollution and other secondary pollutants potentially related to climate change, rather than focusing on only primary emissions, i.e., CO_2 and SO_2. Moreover, this thesis can be replicated on the institutional quality indicators like bureaucracy quality, law and order, corruption, judiciary independence and so on.

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APPENDIX

Table A1. EKC Studies on CO_2 Emissions.

Authors (Year)	Sample	Results (Income)	Other Significant Parameters/Notes
Shafik and Bandyopadhyay (1992)	• 149 nations • 1960-1990 • Panel data	Monotonically increasing	
Holtz-Eakin and Selden (1995)	• 130 nations • 1951-1986 • Panel data	Monotonically increasing	Forecasts: Monotonically increasing
Roberts and Grimes (1997)	• Low-medium-high income nations • 1962-1991	Inverted U-shape rich nations Monotonically increasing low/medium income nations	Social-political factors PIIII
Carson et al. (1997)	• US states • 1990 • Cross-sectional data	Inverted U-shape	
Lim (1997)	• South Korea • 1980s onwards • Time series	Monotonically increasing	
Moomaw and Unruh (1997)	• 16 industrial OECD nations • 1950-1992 • Panel data	N-shape	Oil price shocks
Schmalensee et al. (1998)	• 141 nations • 1950-1990 • Panel data	Inverted U-shape	Forecasts: Monotonically increasing
De Bruyn et al. (1998)	• Netherlands, W. Germany, UK, USA • 1960-1993 intervals • Time series	Monotonically increasing	Population Technology Structural changes
Galeotti and Lanza (1999)	• 110 nations • 1970-1996 • Panel data	Inverted U-shape	Population/Forecasts: Monotonically increasing
Agras and Chapman (1999)	• 34 nations • Various years • Panel data	Monotonically increasing	Energy price (oil shocks)
Borghesi (2000)	• 126 nations • 1988-1995 • Panel data	Monotonically increasing	Income inequality
Perrings and Ansuategi (2000)	• 114 nations • 1990 • Panel data	Monotonically increasing	Share of agriculture in GDP (negatively)

Table A1 *(continued)*

Authors (Year)	Sample	Results (Income)	Other Significant Parameters/Notes
Panayotou et al. (2000)	• 17 developed nations • 1870-1994 • Panel data and time series	Inverted U-shape panel data Inverted U-shape US, UK with time series	Over time, different driving force of EKC
Azomahou and van Phu (2001)	• 100 nations • 1960-1996 • Panel data	Monotonically increasing	
Dijkgraaf and Vollebergh (2001)	• 24 OECD nations • 1960-1997 • Panel data and time series	Inverted U-shape panel data Inverted U-shape time series: 5 nations	Rejection of homogeneity using panel data
Roca and Alcántara (2001)	• Spain • 1972-1997 • Time series	EKC does not exist	
Egli (2002)	• Germany • 1966-1998 • Time series	No conclusion	
Lindmark (2002)	• Sweden • 1870-1997 • Time series	Inverted U-shape	Technological and structural changes (nuclear power)
Pauli (2003)	• 29 OECD nations • 1970-1998 • Panel data	No common EKC: Inverted U-shape 12 nations Monotonically increasing 2 nations Monotonically decreasing 7 nations No conclusion: 8 nations	
Friedl and Getzner (2003)	• Austria • 1960-1999 • Time series	N-shape	PHH Share of tertiary sector in GDP
Cole (2004)	• 21 nations • 1980-1997 • Panel data	Inverted U-shape	PHH
Martínez-Zarzoso and Bengochea-Morancho (2004)	• 22 OECD nations • 1975-1998 • Panel data	N-shape	
Aldy (2005)	• USA states • 1960-1999 • Panel data	Inverted U-shape in few states Monotonically increasing (consumption model)	Emissions-intensive trade Climate conditions Historic coal endowments

Table A1 (*continued*)

Authors (Year)	**Sample**	**Results (Income)**	**Other Significant Parameters/Notes**
Azomahou et al. (2006)	• 100 nations • 1960-1996 • Panel data	Monotonically increasing	
Richmond and Kaufmann (2006)	• 36 nations • 1973-1997 • Panel data	Monotonically increasing	Fuel mix/limited support of a turning point in OECD nations
Lantz and Feng (2006)	• Canada (five regions) • 1970-2000 • Panel data	No significant relationship	Inverted-U shape population U shape technology
Kunnas and Myllyntaous (2007)	• Finland • 1800-2003 • Time series	Monotonically increasing	
Ang (2007)	• France • 1960-2000 • Time series	Inverted U-shape	
Soytas et al. (2007)	• USA • 1960-2004 • Time series	EKC does not exist	
Ang (2008)	• Malaysia • 1971-1999 • Time series	EKC does not exist	
Coondoo and Dinda (2008)	• 88 nations • 1960-1990 • Panel data	Inverted U-shape only for Europe Monotonically increasing for whole	Inter-country income inequality
Auffhammer and Carson (2008)	• 30 Chinese provincial entities • 1985-2004 • Panel data	EKC does not exist	
Lee et al. (2009)	• 89 nations • 1960-2000 • Panel data	N for the whole panel Inverted U-shape in middle income, American and European nations	PHH
Aslanidis and Iranzo (2009)	• 77 Non-OECD nations • 1971-1997 • Panel data	Monotonically increasing	
Dutt (2009)	• 124 nations • 1960-2002 • Panel data	Monotonically increasing 1960-1980 Inverted U-shape 1984-2002	Governance Political Institutions Socioeconomic conditions Education

Table A1 (*continued*)

Authors (Year)	Sample	Results (Income)	Other Significant Parameters/Notes
Chebbi (2009)	• Tunisia • 1971-2004 • Time series	EKC does not exist	
Halıcıoğlu (2009)	• Turkey • 1960-2005 • Time series	Monotonically increasing	Energy consumption Foreign trade
Jalil and Mahmud (2009)	• China • 1971-2005 • Time series	Inverted U-shape	Energy consumption
Akbostanci et al. (2009)	• Turkey • 1968-2003 • Time series	EKC does not exist	
Apergis and Payne (2009)	• 6 Central American nations • 1971-2004 • Panel data	Inverted U-shape	
Narayan and Narayan (2010)	• 43 developing nations • 1980-2004 • Panel data and time series	Inverted U-shape in 15 nations (time series) Inverted U-shape in Middle Eastern and South Asia panels	
Acaravci and Ozturk (2010)	• 19 Europe nations • 1960-2005 • Time series	Inverted U-shape in 2 nations	Energy consumption
He & Richard (2010)	• Canada • 1948-2004 • Time series	EKC does not exist	Oil shock of the 1970s
Akbostanci et al. (2009)	• Turkey • 1968-2003 • Time series	EKC does not exist	
Lean and Smyth (2010)	• 5 ASEAN nations • 1980-2006 • Panel data	Inverted U-shape	
Ozturk and Acaravci (2010)	• Turkey • 1968-2005 • Time series	EKC does not exist	
Iwata et al. (2010)	• France • 1960-2003 • Time series	Inverted U-shape	Nuclear power
Fodha and Zaghdoud (2010)	• Tunisia • 1961-2004 • Time series	Monotonically increasing	Emission reduction policies Investment in pollution abatement expense

Table A1 (*continued*)

Authors (Year)	Sample	Results (Income)	Other Significant Parameters/Notes
Boopen and Vinesh (2011)	• Mauritius • 1975-2009 • Time series	EKC does not exist	
Iwata et al. (2011)	• 28 nations (17 OECD, 11 non-OECD nations) • 1960-2003 • Panel data	Monotonically increasing	Nuclear power
Jaunky (2011)	• 36 high-income nations • 1980-2005 • Panel data	Inverted U-shape in 5 nations Monotonically increasing for whole	
Pao and Tsai (2011)	• Brazil • 1980-2007 • Time series	Inverted U-shape	
Pao et al. (2011)	• Russia • 1990-2007 • Time series	EKC does not exist	
Nasir and Rehman (2011)	• Pakistan • 1972-2008 • Time series	Inverted U-shape	
Muhammad et al. (2011)	• South Africa • 1965-2008 • Time series	Inverted U-shape	Coal consumption Economic growth Financial development Trade openness
Tiwari (2011)	• India • 1971-2007 • Time series	EKC does not exist	
Taguchi and Murofushi (2011)	• All nations • 1850-1990 • Panel data	Monotonically increasing	
Fosten et al. (2012)	• UK • 1830-2003 • Time series	Inverted U-shape	
Saboori et al. (2012)	• Malaysia • 1980-2009 • Time series	Inverted U-shape	
Castiglione et al. (2012)	• 28 nations • 1996-2008 • Panel data	Inverted U-shape	
Ahmed and Long (2012)	• Pakistan • 1971-2008 • Time series	Inverted U-shape	Energy consumption Economic growth Trade
Shahbaz et al. (2012)	• Pakistan • 1971-2009 • Time series	Inverted U-shape	Energy consumption

Table A1 (*continued*)

Authors (Year)	**Sample**	**Results (Income)**	**Other Significant Parameters/Notes**
Kareem et al. (2012)	• China • 1971-2008 • Time series	EKC does not exist	
Hossain (2012)	• Japan • 1960-2009 • Time series	EKC does not exist	
Esteve and Tamarit (2012a, b)	• Spain • 1857-2007 • Time series	EKC does not exist	
Buehn and Farzanegan (2013)	• 122 nations • 1985-2005 • Panel data	Inverted U-shape	Energy efficiency Industrial production Electricity produced from coal sources Demographic transition
Shahbaz et al. (2013)	• Romania • 1980-2010 • Time series	Inverted U-shape	Energy consumption Democratic regime Economic policies Financial development
Kanjilal and Ghosh (2013)	• India • 1971-2008 • Time series	Inverted U-shape	
Baek and Kim (2013)	• Korea • 1971-2007; 1978-2007 • Time series	Inverted U-shape	Economic growth Nuclear energy Fossil fuels in electricity production Energy consumption
Sulaiman et al. (2013)	• Malaysia • 1980-2009 • Time series	Inverted U-shape	
Jebli et al. (2013)	• 25 OECD nations • 1980-2009 • Panel data	Inverted U-shape	GDP Per capita non-renewable energy consumption Per capita real exports and imports Trade openness Use of renewable energy
Tiwari et al. (2013)	• India • 1966-2009 • Time series	Inverted U-shape	Coal consumption Trade openness
Hassan et al. (2015)	• Pakistan • 1980-2011 • Time series	Inverted U-shape	Economic growth Inequality Poverty
Pérez-Suárez and López-Menéndez (2015)	• 175 nations • 1860-2012 • Panel data	N-shape Inverted-N shape	
Apergis (2016)	• 15 nations • 1960-2013 • Panel data	Inverted U-shape	

Table A2. EKC Studies on SO_2 Emissions.

Authors (Year)	**Sample**	**Results (Income)**	**Other Significant Parameters/Notes**
Grossman and Krueger (1991)	• Up to 52 cities in up to 32 nations • 1977, 1982, 1988 • Cross-sectional data	Inverted U-shape	Locational dummies, population density, trend
Panayotou (1993)	• 55 developed and developing nations • 1987-1988 • Cross-sectional data	Inverted U-shape	
Shafik (1994)	• 47 cities in 31 nations • 1972-1988 • Panel data	Inverted U-shape	Time trend, locational dummies
Selden and Song (1994)	• 22 OECD and 8 developing nations • 1979-1987 • Panel data	Inverted U-shape	Population density
Panayotou (1997)	• Cities in 30 developed and developing nations • 1982-1994 • Cross-sectional and time series data	Inverted U-shape	Population density, policy variables
Cole, Rayner, and Bates (1997)	• 11 OECD nations • 1970-1992 • Panel data	Inverted U-shape	National dummy, technology level
Torras and Boyce (1998)	• Unknown number of cities in 42 nations • 1977-1991 • Panel data	Inverted U-shape	Income inequality, literacy, political and civil rights, urbanization, locational dummies
Kaufmann, Davidsdottir, Garnham, and Pauly (1998)	• 13 developed and 10 developing nations • 1974-1989 • Panel data	Inverted U-shape	GDP/Area, steel exports/GDP

Table A2 (*continued*)

Authors (Year)	Sample	Results (Income)	Other Significant Parameters/Notes
List and Gallet (1999)	• The US States • 1929-1994 • Panel data	Inverted U-shape	
Dinda et al. (2000)	• 33 low, middle and high income nations • 1979-1982; 1983-1986; 1987-1990 • Cross-country time series	U-shape	Economy-level capital intensity Sectoral composition of GDP Rate of growth of GDP
Stern and Common (2001)	• 73 developed and developing nations • 1960-1990 • Panel data	Inverted U-shape	Time and national-related effects
Roca et al. (2001)	• Spain • 1980-1996 • Time series	Inverted U-shape	
Stern (2002)	• 64 nations • 1973-1990 • Panel data	Inverted U-shape for OECD nations Monotonically increasing for world and non-OECD nations	Time and national-related effects
Perman and Stern (2003)	• 74 nations • 1960-1990 • Panel data	U-shaped for over one third of the nations No EKC-pattern for a large minority of nations	
Millimet et al. (2003)	• The US states • 1929-1994 • Panel data	Inverted U-shape	
Deacon and Norman (2006)	• 25 nations • 1976-1986 • Panel data	Multiple turnaround points	
Stern (2006)	• 82 nations • 1971-1990 • Panel data	Inverted U-shape	
Shen (2006)	• Chinese provinces • 1993-2002 • Panel data	U-shape	
Yaguchi et al. (2007)	• China (1985-1999) • Japan (1975-1999) • Time series	Multiple turn around points	
Akbostanci et al. (2009)	• Turkey • 1992-2001 • Time series	N-shaped	

Table A2 (*continued*)

Authors (Year)	Sample	Results (Income)	Other Significant Parameters/Notes
Llorca and Meunié (2009)	• Chinese provinces • 1990-1999 • Panel data	Linearly increasing	
Lamla (2009)	• 47 nations • 1980-2000 • Panel data	Inverted U-shape	
Leitão (2010)	• 94 nations • 1981-2000 • Panel data	Inverted U-shape	Corruption
Fodha and Zaghdoud (2010)	• Tunisia • 1961-2004 • Time series	Inverted U-shape	Emission reduction policies Investment in pollution abatement expense
Taguchi and Murofushi (2011)	• All nations • 1850-1990 • Panel data	Inverted U-shape	
Park and Lee (2011)	• 16 metropolitan regions in Korea • 1990-2005 • Panel data	No one-dominant shape of EKC	Energy consumption
Xiaoyu et al. (2011)	• Chinese provinces • 2003-2008 • Panel data	Inverted U-shape	
Fosten et al. (2012)	• UK • 1830-2003 • Time series	Inverted U-shape	
Al Sayed and Sek (2013)	• 40 nations • 1961-2009 • Panel data	Inverted U-shape	
Buehn and Farzanegan (2013)	• 122 nations • 1985-2005 • Panel data	Inverted U-shape	Energy efficiency Industrial production Electricity produced from coal sources Demographic transition
Kayalica and Kaçar (2014)	• 42 nations • 1991-2000 • Panel data	Inverted U-shape	
Sinha (2016)	• 139 Indian cities • 2001-2013 • Panel data	Inverted U-shape	Economic growth Inequality in energy intensity
Wang et al. (2016)	• Chinese provinces • 1990-2012 • Panel data	Inverted U-shape	

Table B1. List of Nations and Sample Period for LCO$_2$pc.

Nation	Sample period
Albania, Algeria, Australia, Austria, Bangladesh, Benin, Bolivia, Botswana, Brazil, Bulgaria, Cameroon, Chile, China, Colombia, Congo Democratic Republic, Congo Republic, Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Denmark, Dominican Republic, Ecuador, Egypt Arab Republic, El Salvador, Ethiopia, Finland, France, Ghana, Honduras, India, Indonesia, Iran Islamic Republic, Italy, Japan, Jordan, Kenya, Korea Republic, Malaysia, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Nepal, Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Panama, Philippines, Romania, Saudi Arabia, Senegal, Singapore, South Africa, Sri Lanka, Sudan, Sweden, Switzerland, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, Uruguay, Venezuela Republic, Vietnam, Zambia	1990-2011
Armenia, Azerbaijan, Belarus, Georgia, Kyrgyz Republic, Moldova, Tajikistan, Turkmenistan, Ukraine, Uzbekistan	LCO$_2$PC: 1992-2011 POLITY2: 1991-2011
Bahrain	INDUS: 1990-1995 LRGDPPCPPP: 1990-1995
Belgium, Luxembourg	AREA: 2000-2011 INDUS: 1995-2011
Cambodia	ALTERNATIVE_ENERGY: 1995-2011 COAL_ENERGY: 1995-2011 INDUS: 1993-2011 LENERGY_EFFICIENCY: 1995-2011 LRGDPPCPPP: 1993-2011
Croatia, Estonia	LCO$_2$PC: 1992-2011 INDUS: 1995-2011 LENERGY_EFFICIENCY: 1995-2011 LRGDPPCPPP: 1995-2011 POLITY2:1991-2011
Czech Republic	LCO$_2$PC: 1992-2011 INDUS: 1993-2011 POLITY2: 1993-2011
Eritrea	LCO$_2$PC: 1994-2011 ALTERNATIVE_ENERGY: 1992-2011 COAL_ENERGY: 1992-2011 INDUS: 1992-2009 LENERGY_EFFICIENCY: 1992-2011 LRGDPPCPPP: 1992-2011 POLITY2: 1993-2011

Table B1 *(continued)*

Nation	Sample period
Gabon	INDUS: 2001-2011
Germany	LCO$_2$PC: 1991-2011 INDUS: 1991-2011
Greece, Ireland, Poland, Portugal, Spain	INDUS: 1995-2011
Guatemala	INDUS: 2001-2011
Hungary	INDUS: 1995-2011 LENERGY_EFFICIENCY: 1991-2011 LRGDPPCPPP: 1991-2011
Jamaica	INDUS: 1993-2011
Kazakhstan	LCO$_2$PC: 1992-2011 INDUS: 1992-2011 POLITY2:1991-2011
Latvia, Lithuania, Slovenia	LCO$_2$PC: 1992-2011 INDUS: 1995-2011 LENERGY_EFFICIENCY: 1995-2011 LRGDPPCPPP: 1995-2011 POLITY2:1991-2011
Lebanon	INDUS: 1994-2011 POLITY2: 2005-2011
Libya	INDUS: 2002-2008 LENERGY_EFFICIENCY: 1999-2011 LRGDPPCPPP: 1999-2011
Macedonia, FYR	LCO$_2$PC: 1992-2011 POLITY2:1991-2011
Namibia	ALTERNATIVE_ENERGY: 1991-2011 COAL_ENERGY: 1991-2011 LENERGY_EFFICIENCY: 1991-2011
Nicaragua	INDUS: 1994-2011
Paraguay	ALTERNATIVE_ENERGY: 1990-1996; 2001; 2010 INDUS: 1991-2011
Peru	INDUS: 1991-2011
Qatar	INDUS: 2000-2011 LENERGY_EFFICIENCY: 2000-2011 LRGDPPCPPP: 2000-2011
Russian Federation	LCO$_2$PC: 1992-2011 POLITY2:1992-2011
Slovak Republic	LCO$_2$PC: 1992-2011 INDUS: 1995-2011 LENERGY_EFFICIENCY: 1992-2011 LRGDPPCPPP: 1992-2011 POLITY2:1993-2011
United Arab Emirates	INDUS: 2001-2007
United States	INDUS: 1997-2011
Yemen Republic	INDUS:1990-2006
Zimbabwe	INDUS:1990-1999; 2004-2011

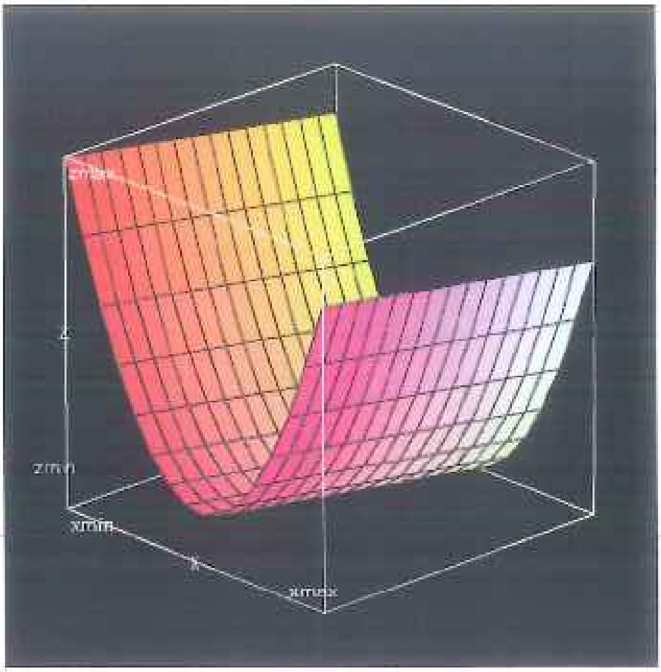
Table B2. List of Nations and Sample Period for LSO$_2$pc.

Nation	Sample period
Albania, Algeria, Australia, Austria, Bangladesh, Benin, Bolivia, Botswana, Brazil, Bulgaria, Cameroon, Chile, China, Colombia, Congo Democratic Republic, Congo Republic, Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Denmark, Dominican Republic, Ecuador, Egypt Arab Republic, El Salvador, Ethiopia, Finland, France, Ghana, Honduras, India, Indonesia, Iran Islamic Republic, Italy, Japan, Jordan, Kenya, Korea Republic, Malaysia, Mexico, Mongolia, Morocco, Mozambique, Nepal, Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Panama, Philippines, Romania, Saudi Arabia, Senegal, Singapore, South Africa, Sri Lanka, Sudan, Sweden, Switzerland, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, Uruguay, Venezuela Republic, Vietnam, Yemen Republic, Zambia	1990-2005
Armenia, Azerbaijan, Belarus, Georgia, Kyrgyz Republic, Moldova, Tajikistan, Turkmenistan, Ukraine, Uzbekistan	FREDOM: 1991-2005
Bahrain	INDUS: 1990-1995 LRGDPPCPPP: 1990-1995
Belgium, Luxembourg	AREA: 2000-2005 INDUS: 1995-2005
Cambodia	ALTERNATIVE_ENERGY: 1995-2005 COAL_ENERGY: 1995-2005 INDUS: 1993-2005 LENERGY_EFFICIENCY: 1995-2005 LRGDPPCPPP: 1993-2005
Croatia, Estonia	FREEDOM: 1991-2005 INDUS: 1995-2005 LENERGY_EFFICIENCY: 1995-2005 LRGDPPCPPP: 1995-2005
Czech Republic	FREEDOM: 1993-2005 INDUS: 1993-2005
Eritrea	ALTERNATIVE_ENERGY: 1992-2005 COAL_ENERGY: 1992-2005 FREEDOM: 1993-2005 INDUS: 1992-2005 LENERGY_EFFICIENCY: 1992-2005 LRGDPPCPPP: 1992-2005
Gabon	INDUS: 2001-2005
Germany	INDUS: 1991-2005
Greece, Ireland, Poland, Portugal, Spain	INDUS: 1995-2005
Guatemala	INDUS: 2001-2005

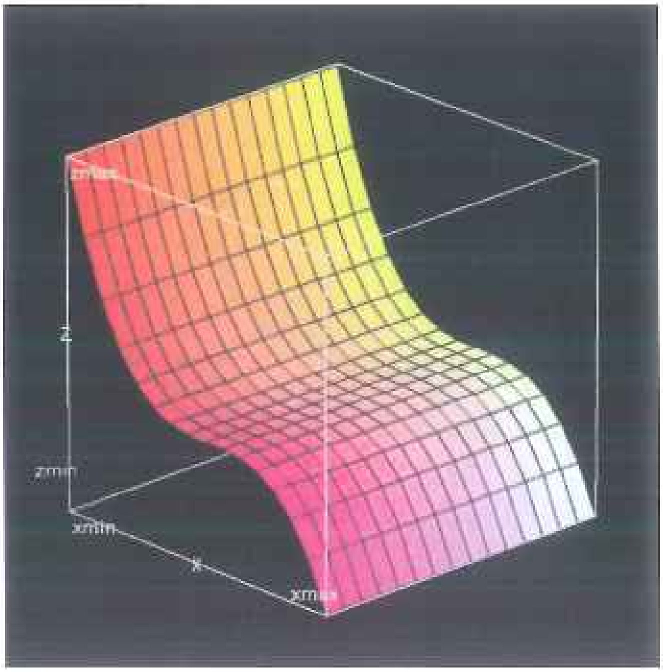
Table B2 *(continued)*

Nation	Sample period
Hungary	INDUS: 1995-2005 LENERGY_EFFICIENCY: 1991-2005 LRGDPPCPPP: 1991-2005
Jamaica	INDUS: 1993-2005
Kazakhstan	FREEDOM:1991-2005 INDUS: 1992-2005
Latvia, Lithuania, Slovenia	FREEDOM:1991-2005 INDUS: 1995-2005 LENERGY_EFFICIENCY: 1995-2005 LRGDPPCPPP: 1995-2005
Lebanon	INDUS: 1994-2005 POLITY2: 2005
Libya	INDUS: 2002-2005 LENERGY_EFFICIENCY: 1999-2005 LRGDPPCPPP: 1999-2005
Macedonia, FYR	FREEDOM:1992-2005
Namibia	ALTERNATIVE_ENERGY: 1991-2005 COAL_ENERGY: 1991-2005 LENERGY_EFFICIENCY: 1991-2005
Nicaragua	INDUS: 1994-2005
Paraguay	ALTERNATIVE_ENERGY: 1990-1996; 2001 INDUS:1991-2005
Peru	INDUS: 1991-2005
Qatar	INDUS: 2000-2005 LENERGY_EFFICIENCY: 2000-2005 LRGDPPCPPP: 2000-2005
Russian Federation	FREEDOM:1991-2005
Slovak Republic	FREEDOM: 1993-2005 INDUS: 1995-2005 LENERGY_EFFICIENCY: 1992-2005 LRGDPPCPPP: 1992-2005
United Arab Emirates	INDUS: 2001-2005
United States	INDUS: 1997-2005
Zimbabwe	INDUS:1990-1999; 2004-2005

Table 1C. Diagrammatic Representations of the Estimated Per Capita CO_2 Emissions, Per Capita Real GDP and Energy Efficiency (where x, y and z represent per capita GDP, energy efficiency and CO_2 metric ton per capita, respectively).

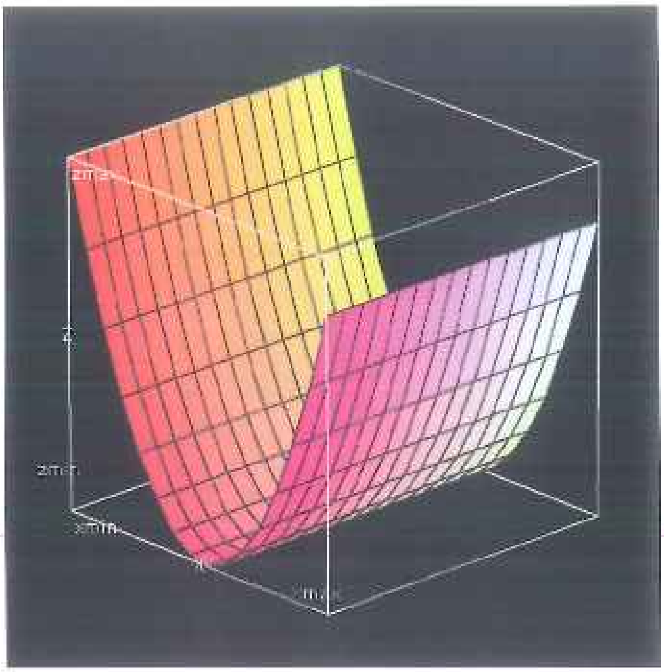


i. U-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Energy Efficiency in Model 1.

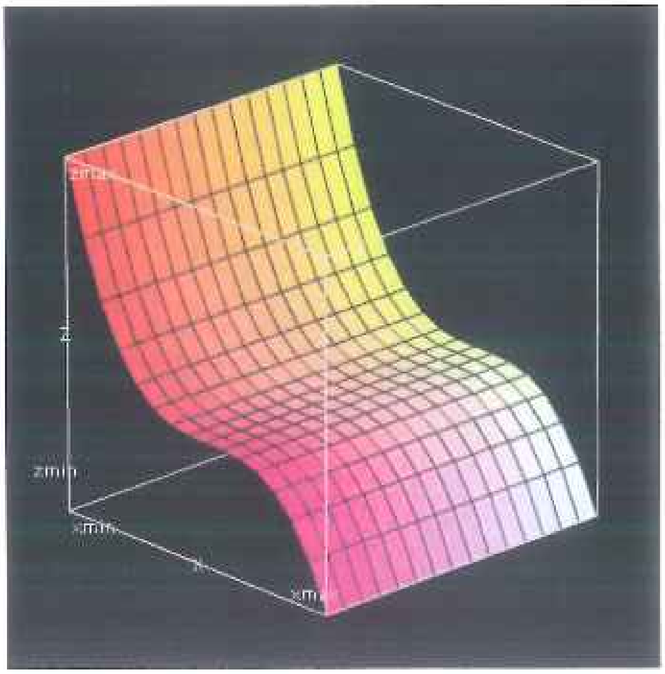


ii. Inverted N-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Energy Efficiency in Model 2.

Table 2C. Diagrammatic Representations of the Estimated Per Capita CO_2 Emissions, Per Capita Real GDP and Alternative Energy (where x, y and z represent per capita GDP, alternative energy and CO_2 metric ton per capita, respectively).

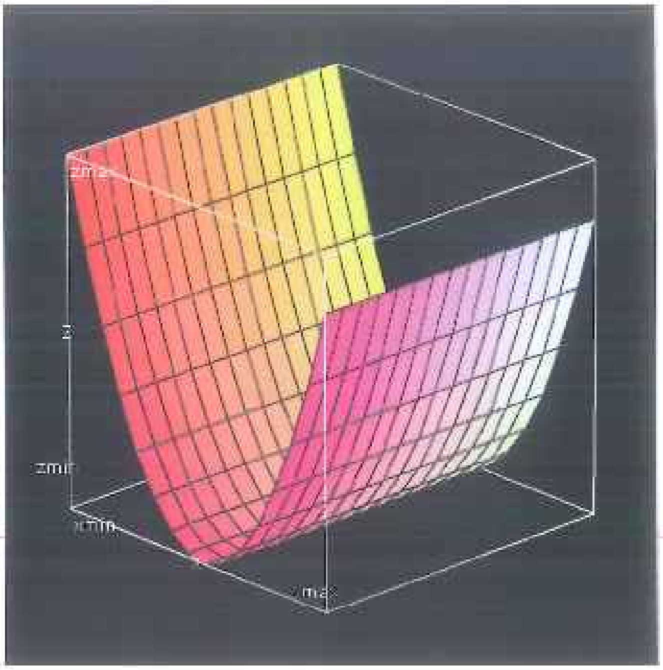


i. U-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Alternative Energy in Model 1.

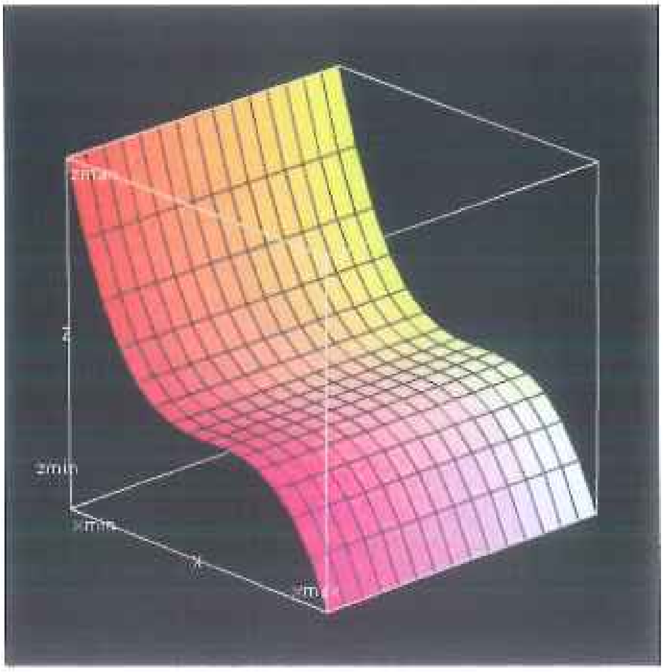


ii. Inverted N-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Alternative Energy in Model 2.

Table 3C. Diagrammatic Representations of the Estimated Per Capita CO_2 Emissions, Per Capita Real GDP and Coal Energy (where x, y and z represent per capita GDP, coal energy and CO_2 metric ton per capita, respectively).

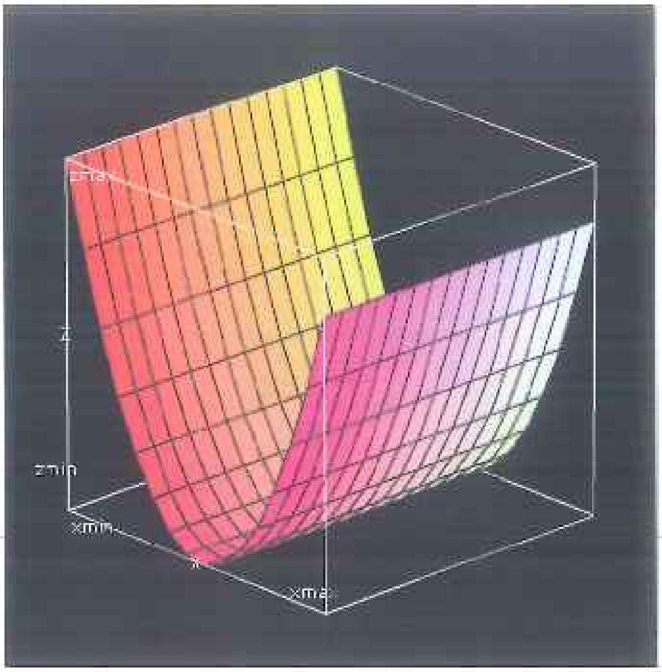


i. U-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Coal Energy in Model 1.

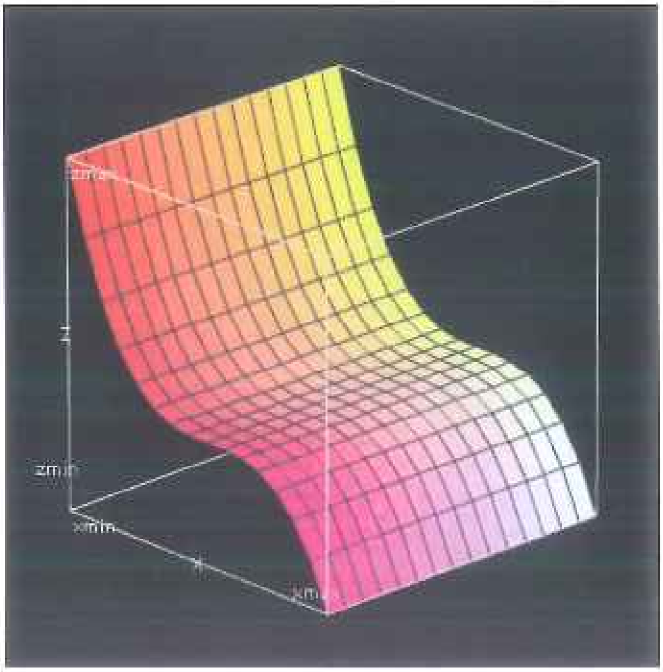


ii. Inverted N-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Coal Energy in Model 2.

Table 4C. Diagrammatic Representations of the Estimated Per Capita CO_2 Emissions, Per Capita Real GDP and Industry (where x, y and z represent per capita GDP, industry and CO_2 metric ton per capita, respectively).

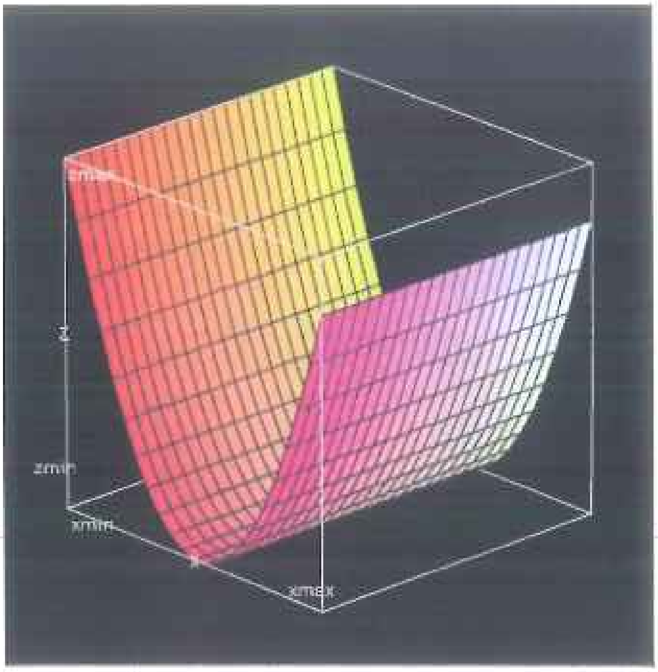


i. U-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Industry in Model 1.

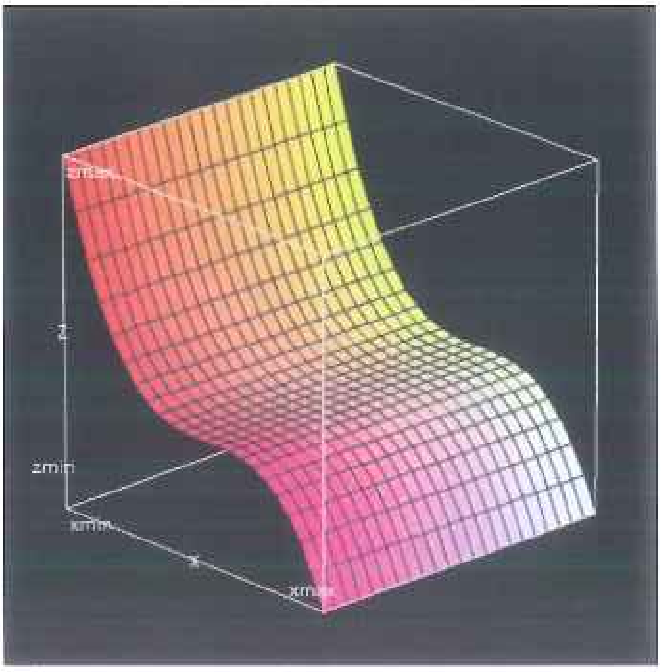


ii. Inverted N-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Industry in Model 2.

Table 5C. Diagrammatic Representations of the Estimated Per Capita CO_2 Emissions, Per Capita Real GDP and Polity2 (where x, y and z represent per capita GDP, polity2 and CO_2 metric ton per capita, respectively).

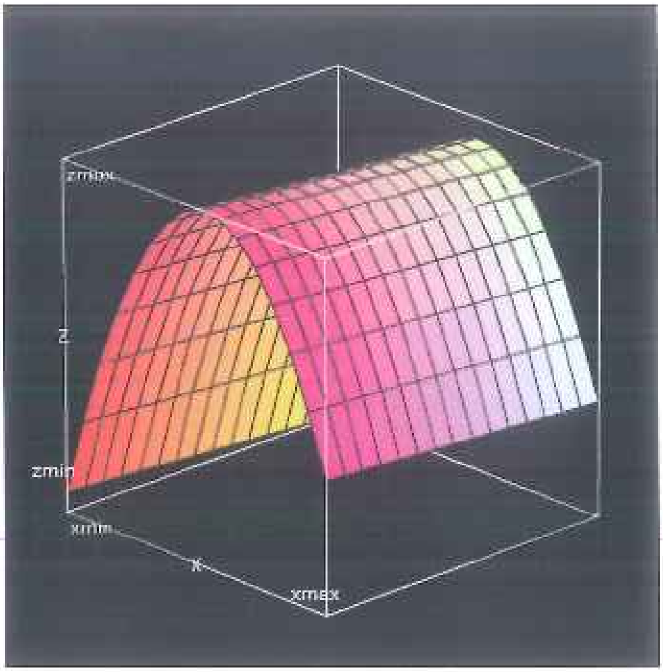


i. U-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Polity2 in Model 1.

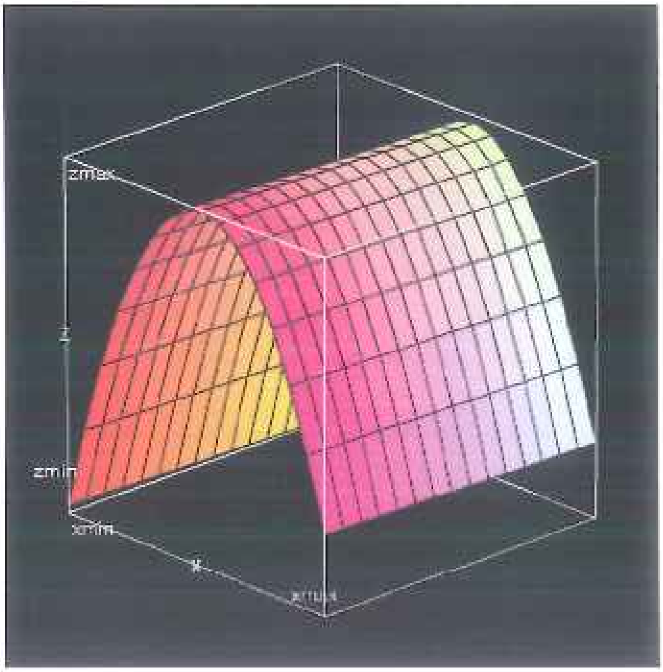


ii. Inverted N-Shaped EKC: CO_2 Metric Ton Per Capita vs. Per Capita GDP and Polity2 in Model 2.

Table 1D. Diagrammatic Representations of the Estimated Per Capita SO_2 Emissions, Per Capita Real GDP and Energy Efficiency (where x, y and z represent per capita GDP, energy efficiency and SO_2 metric ton per capita, respectively).

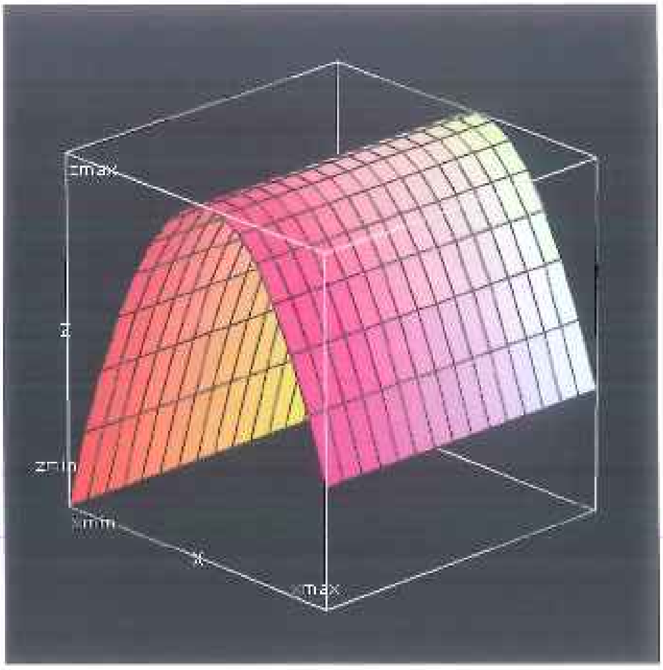


i. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Energy Efficiency in Model 1.

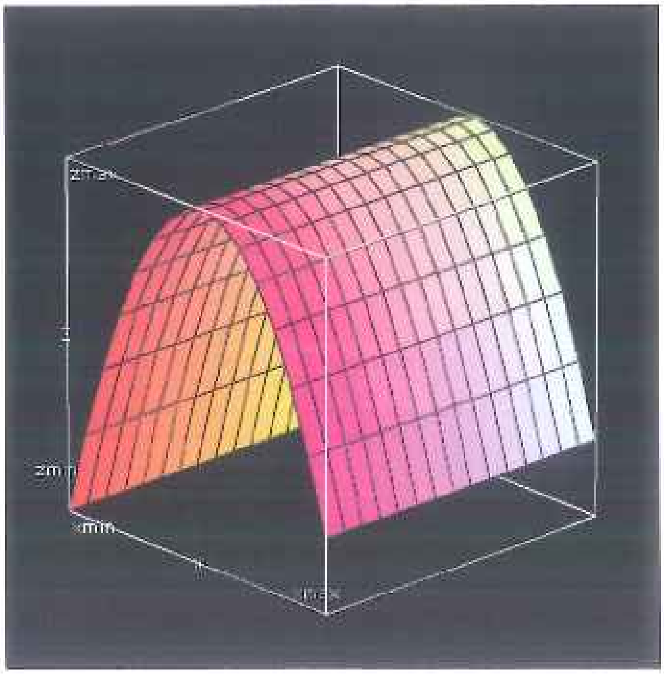


ii. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Energy Efficiency in Model 2.

Table 2D. Diagrammatic Representations of the Estimated Per Capita SO_2 Emissions, Per Capita Real GDP and Alternative Energy (where x, y and z represent per capita GDP, alternative energy and SO_2 metric ton per capita, respectively).

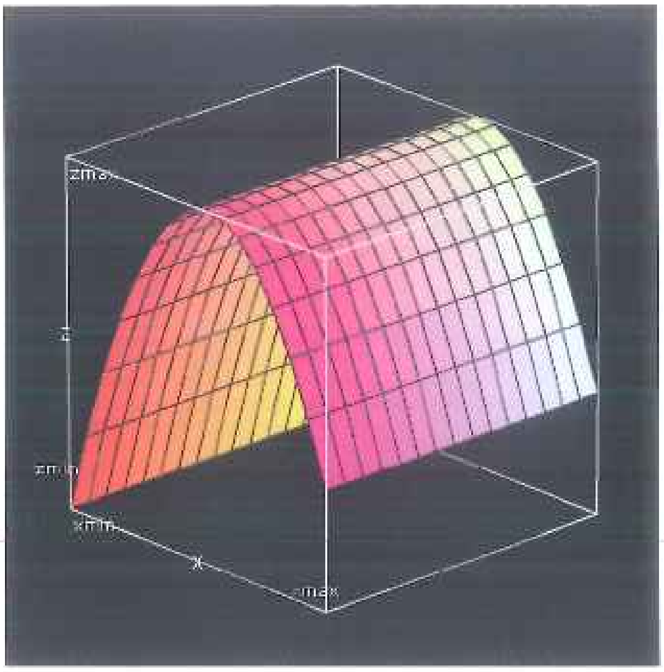


i. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Alternative Energy in Model 1.

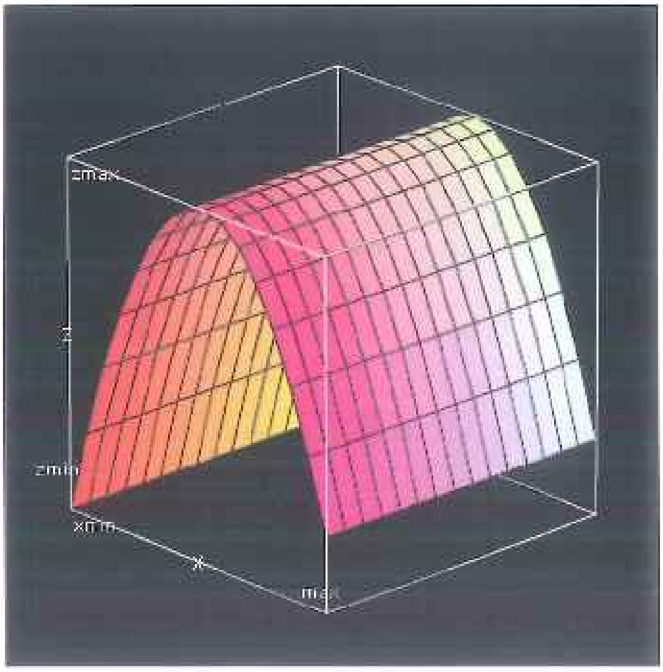


ii. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Alternative Energy in Model 2.

Table 3D. Diagrammatic Representations of the Estimated Per Capita SO_2 Emissions, Per Capita Real GDP and Coal Energy (where x, y and z represent per capita GDP, coal energy and SO_2 metric ton per capita, respectively).

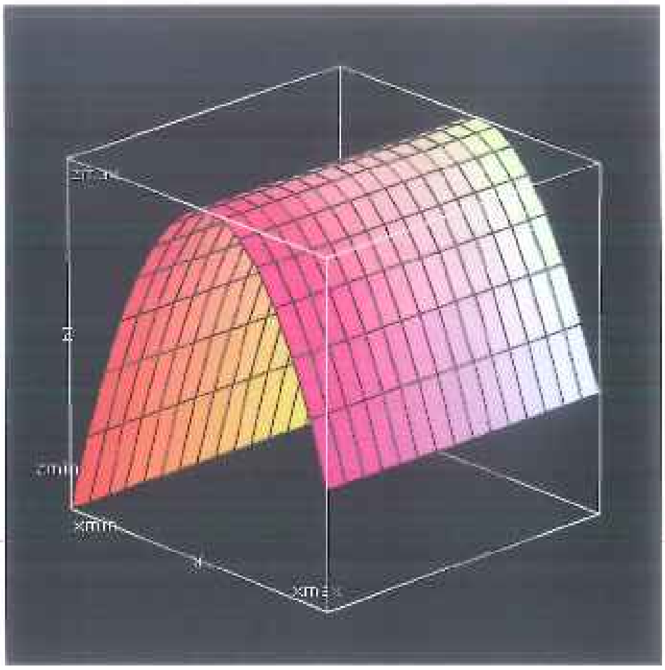


i. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Coal Energy in Model 1.

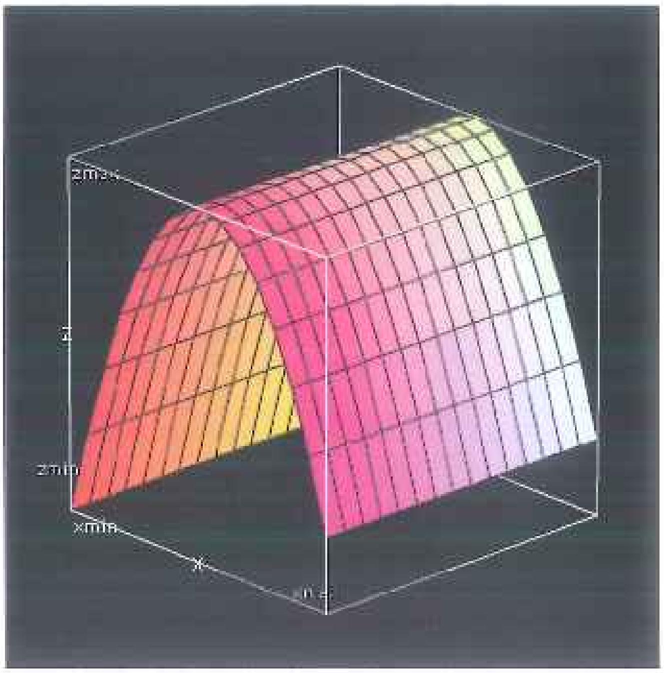


ii. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Coal Energy in Model 2.

Table 4D. Diagrammatic Representations of the Estimated Per Capita SO_2 Emissions, Per Capita Real GDP and Industry (where x, y and z represent per capita GDP, industry and SO_2 metric ton per capita, respectively).

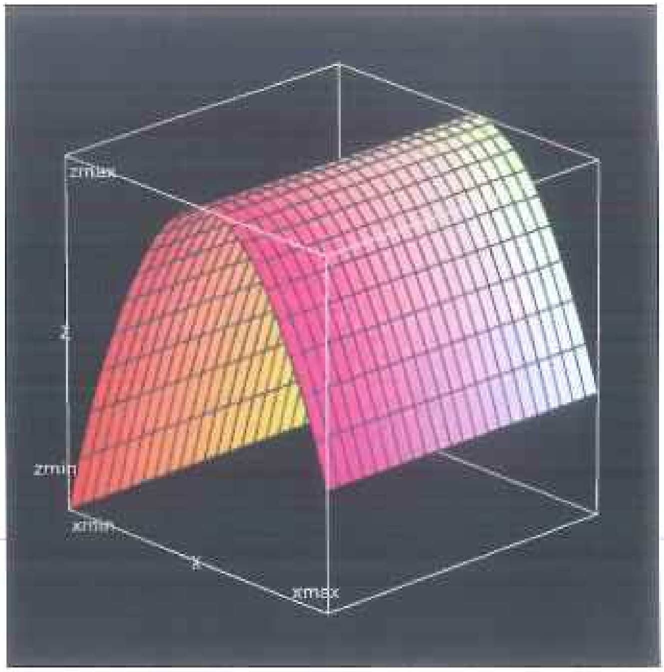


i. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Industry in Model 1.

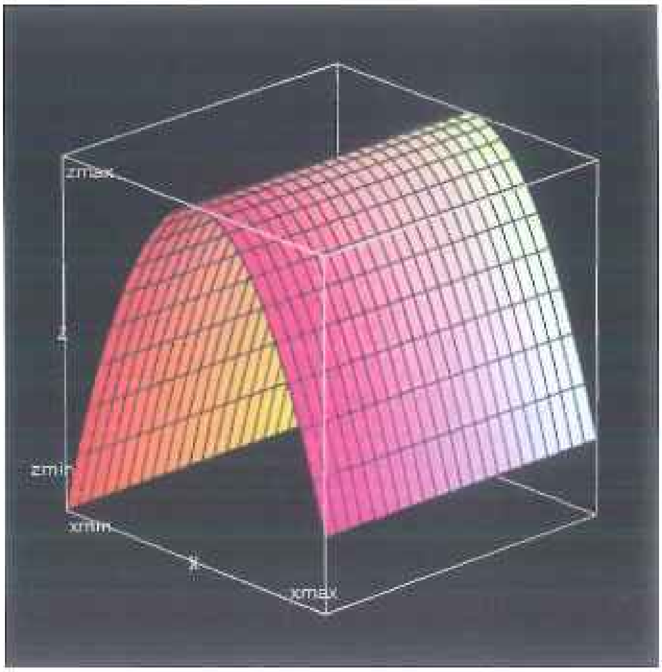


ii. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Industry in Model 2.

Table 5D. Diagrammatic Representations of the Estimated Per Capita SO_2 Emissions, Per Capita Real GDP and Freedom (where x, y and z represent per capita GDP, freedom and SO_2 metric ton per capita, respectively).



i. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Freedom in Model 1.



ii. Inverted U-Shaped EKC: SO_2 Metric Ton Per Capita vs. Per Capita GDP and Freedom in Model 2.