ECONOMIC GROWTH AND ENVIRONMENT NEXUS: ENVIRONMENTAL KUZNETS CURVE

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ABSTRACT

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Carbon dioxide (CO_2) is one of the most important Green House Gases (GHGs) for contributing to global climate change. Human influence on earth through economic development is clearly emitting immense amount of CO_2 emissions. Hence, examining the relationship between CO_2 emissions and economic growth is crucial. In this study, the relationship between income and CO_2 emissions in the context of the Environmental Kuznets Curve (hereafter EKC), which posits the existence of an inverted U-shape relationship between environmental degradation and economic development, is empirically investigated. For this purpose, three empirical models are examined. For all models, the relationship between per capita income and per capita CO_2 emissions and the relationship among per capita income, per capita energy use, and per capita CO_2 emissions are analyzed respectively for the period of 1980 – 2010, using the panel data estimation techniques, then Driscoll-Kraay Standard Errors is applied. Yet, for the first model, data are analyzed for 26 OECD countries with high income levels, while for the second model; data are examined for 52 emerging countries. Lastly, third model is formed for 88 countries according to data availability. The results of three models show that all analyses give U-shape relationship for quadratic functional form, while both N-shape and an inverted N-shape relationship for cubic functional form are observed. To sum up, the results of our panel data analysis do not support the EKC hypothesis. That is, environmental degradation cannot be solved automatically by economic growth.

Keywords: Environmental Kuznets Curve, EKC, CO_2 emissions, panel data

ÖZ

EKONOMİK GELİŞME VE ÇEVRE BAĞI, ÇEVRESEL KUZNETS EĞRİSİ

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Karbondioksit (CO_2) iklim değişikliğine katkıda bulunan en önemli sera gazlarından bir tanesidir. İnsanın yeryüzüne etkisi ekonomik gelişmeyle birlikte açık bir şekilde çok büyük miktarlarda CO_2 emisyonu salınımına neden olmaktadır. Dolayısı ile CO_2 emisyonu ve ekonomik gelişme arasındaki ilişkiyi incelemek çok önemlidir. Bu çalışma, gelir ve CO_2 emisyonu arasındaki ilişki, çevresel tahribat ve ekonomik gelişme arasındaki ilişkiyi ters U şeklinde olduğunu varsayan Çevresel Kuznets Eğrisi (ÇKE) bağlamında ampirik olarak araştırmaktadır. Bu amaçla, üç ampirik model incelenmiştir. Bütün modellerde de, sırasıyla, 1980-2010 zaman aralığındaki, kişi başına düşen gelir ve kişi başına düşen CO_2 emisyonu arasındaki ilişki ve kişi başı gelir, kişi başı enerji kullanımı ve kişi başı CO_2 emisyonu aralarındaki ilişkiler veri tahmin teknikleri kullanılarak analiz edilmekte, sonrasında Driscoll-Kraay Standart Hatalar uygulanmaktadır. Birinci modelde, 26 yüksek gelirli OECD ülkeleri için veriler analiz edilirken, ikinci model için bu 52 gelişmekte olan ülkeye uygulanmıştır. Son olarak, üçüncü model, veri bulunmasına bağlı olarak, 88 ülke için oluşturulmuştur. Üç modelin de sonuçlarına göre karesel foksiyon formu için bütün analizler U şeklinde ilişki verirken, kübik fonksiyon formu için hem N şeklinde hem de ters N şeklinde ilişki bulunmuştur. Özetlemek gerekirse, panel veri analizlerimizin sonuçları ÇKE hipotezini desteklememektedir. Yani, sonuç olarak çevresel tahribatın otomatik olarak ekonomik gelişmeyle çözülemeyeceği ortaya çıkmaktadır.

Anahtar Kelimeler: Çevresel Kuznets Eğrisi, ÇKE, CO_2 emisyonu, panel veri

to the mother earth...

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CHAPTER 1

INTRODUCTION

Climate change is a disaster which human beings have had to cope with for decades. Excess amount of greenhouse gases (GHGs) which are namely water vapor, Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and Chlorofluorocarbons (CFCs) in the atmosphere are the main reason for global climate change. This phenomenon is leading our world to a dramatic transformation in upcoming years, because GHGs absorb heat arriving from the Sun and trap it in the atmosphere which causes an increase in earth surface temperature. Although to some extent GHGs are required to have a life on earth, too much GHGs jeopardize life on it. This unbalanced proportion of GHGs in atmosphere and its complications on earth is so called climate change. There are enough indicators to prove the change in climate such as increasing earth surface temperature, melting ice caps, rising sea levels, changing precipitation patterns, and decreasing fresh water supplies. The International Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5, 2014) asserts that human influence on the climate system is obvious. Economic and population growth after the industrial revolution have profoundly caused a rise in GHGs emissions; hence, global climate changes. It seems that the latest climate change is not a natural phenomenon; we have been experiencing unnatural change in climate in the last decades due to human intervention on earth.

Among the various GHGs which cause the global climate change, CO_2 is not the most abundant. However, its excess can be directly related to human activities such as combusting fossil fuels, transportations, deforestation, clearing lands for agricultural purposes, and cement production which intensified after the industrial revolution. It appears that increasing the amount of CO_2 emissions intensifies climate change and environmental problems. In other words, human influence on climate change and eventually on the environment is a major problem. That is why endeavors for decreasing CO_2 emissions were brought to international arena with the pioneering role of the United Nations (UN).

After the publication of Silent Spring (1962), Rachel Carson's book about the effect of DDT on birds and biological diversity, environmental issues came on the stage. Whilst discussions related to environmental issues were ongoing mainly among conservation biologists, the UN prepared an international conference in Stockholm in order to draw attention to human environment in 1972. This was the very first international conference in the history of global environmental issues. Later on, in 1987, the Brundtland Report was published and the sustainable development concept was announced in this report. Sustainable development encompasses environment, society, and economics within. This notion provided a wider point of view of global environmental and climate change issues. In the 1992, Rio Conference environmentalists and ecologists highlighted the importance of reducing GHGs, especially CO_2 emissions. In fact, this conference prepared a ground for an internationally binding agreement. As a result, the Kyoto Protocol was launched in 1997 as a binding agreement for industrialized countries. Although it was not ratified by United States (US), one of the biggest polluter for centuries, it was still a big step in the way for international environmental law.

At the same time, especially growth and development economists started to worry about the continuity of the production in economies while environmental issues were evolving. Kaika & Zervas (2013) unfolded that growth economists were concerned for the economic situation because of scarcity of natural resources. Since scarcity of natural resources may risk the available and increasing production in economies, interests of economists and environmentalists confronted. This conflict yielded the Environmental Kuznets Curve (hereafter EKC) extrapolated from empirical research of growth and trade economists. The EKC posits that environmental degradation increases at the initial stage of economic growth. However, reaching a certain level of economic growth reversed this process; that is, environmental degradation declines with the rise in economic growth. The plotted graph between income and environmental deterioration results in a bell shaped curve or mostly called an inverted U-shape curve. Panayotou (1993) stated that the similarity of this curve to the Kuznets curve demonstrates the relationship between income and income inequality, it was named EKC.

Even though there has been plenty of research on the relationship between environmental degradation and economic growth, empirical studies of Grossman & Krueger (1991), Shafik & Bandyopadhyay (1992), and Panayotou (1993) are accepted as cornerstones of the EKC hypothesis. In general, air pollution, water pollution, CO_2 emissions, deforestation etc. are treated as environmental degradation and GDP per capita is treated as an indicator of economic growth in these studies. Energy use, population density, trade, civil liberties, education are some of the explanatory variables added to the research in addition to income. He & Richard (2010) highlighted that most of the theoretical and empirical studies support the validity of the EKC for local pollutants like sulfure dioxide (SO_2) emissions, wastewater discharge and carbon monoxide (CO) emissions. Nevertheless, the existence of the EKC for CO_2 emissions is still under discussion. Aforementioned, CO_2 emissions are the most significant GHGs to mitigate the climate change because it is primarily caused by human activities. That is why this study is built on investigating the relationship between CO_2 emissions and income.

Other than the relationship between income and environmental impacts, there has been growing literature about the link between energy, environment, and income (Bölük & Mert, 2014, p.440). Energy is a fundamental input for not only production but also consumption; that is, it is the basis of economic growth. At this stage, focusing on the connection between energy, environment, and income as well as the basic EKC concept is contributing to growing literature because carrying out both sides of the analysis gives us an opportunity to make a comparison between the two branches of the EKC.

The EKC hypothesis emphasizes that environmental problems, which are mostly resulted from economic development, can be avoided with sufficient economic growth in both developed and underdeveloped economies if the EKC is valid (Caviglia-Harris, Chambers, & Kahn, 2009, p.1149). Frankly, the discussions about global environmental issues have been biased in order to follow the EKC hypothesis. Environmentalists used to be opposed to economic growth devastates the environment. However, economists claim that environmental problems can be solved automatically in the long run with economic growth even if it harms the environment at the beginning. Hence, the nexus between environmental change and economic growth has been breaking because the cause of the problem is offered as the solution.

In this thesis, the relationship between GDP per capita and per capita CO_2 emissions is empirically investigated in relation to global climate change and the idea that climate change can be mitigated through economic growth. That is, the study is to detect the inverted U-shape relationship between CO_2 emissions and income. After Kyoto Protocol, international attention has gathered especially on CO_2 emissions. That is why this study is focusing on CO_2 emissions as an environmental indicator (Huang, Lee & Wu, 2008, p.240). Moreover, the energy, environment, and economic growth nexus is searched in this study. For this purpose, three parametric models are formed according to income level. The first model is set for 26 high income OECD countries. The data set cover the time horizon between 1980 and 2010. Panel data estimation techniques for quadratic and cubic functional forms are used to check the existence of the EKC. Then the model is reformed by adding per capita energy use as an explanatory variable so that the energy, environment, and economic growth nexus can be detected. Furthermore, the second model is established for 52 emerging countries according to available data. The time horizon and the functional specifications remain the same as the first model. Later on, the model is extended by the addition of the per capita energy use. Finally, the third model is a combination of the first and the second models; however, it differs as it includes more states than the summation of both models. This model is formed by data from 88 countries all over the world with respect to the availability of the data. Whilst the same time periods and model specifications are used in this model, the per capita energy use is later added to the model in order to examine the nexus between energy, environment, and economic growth.

The outline of this thesis as follows: In Chapter 2, the definition of the EKC and the brief history about global environmental issues are presented. Chapter 3 highlights the conceptual background of the EKC. While measurements of the EKC are listed in Chapter 4, the models and methodology used in the EKC literature are described in Chapter 5. Chapter 6 details the data set and the models for the investigation. Chapter 7 exhibits the empirical analyses checking for the validity of the EKC between per capita income and per capita CO_2 emissions as well as the existence of the EKC hypothesis detected among per capita income, per capita energy use, and per capita CO_2 emissions through the panel data estimation technique. Finally, Chapter 8 concludes with the summary of the empirical findings.

CHAPTER 2

THE DEFINITION OF THE EKC

The EKC hypothesis has begun to take a shape with the beginning of growth related policies. Many researchers assert that environmental degradation is triggered by a higher level of income that is an expected result of the economic growth (Dinda, 2004, p.464). However, there are some scholars think oppositely that high income results in better environmental quality instead of worsening it. Conducting the empirical studies about the debate of environment versus growth initiated an actual EKC literature. In this sense, studies of Grossman & Krueger (1991), Shafik & Bandyopadhyay (1992), and Panayotou (1993) are ground works of the EKC concept that examining the empirical relationship between GDP per capita and environmental pollution.

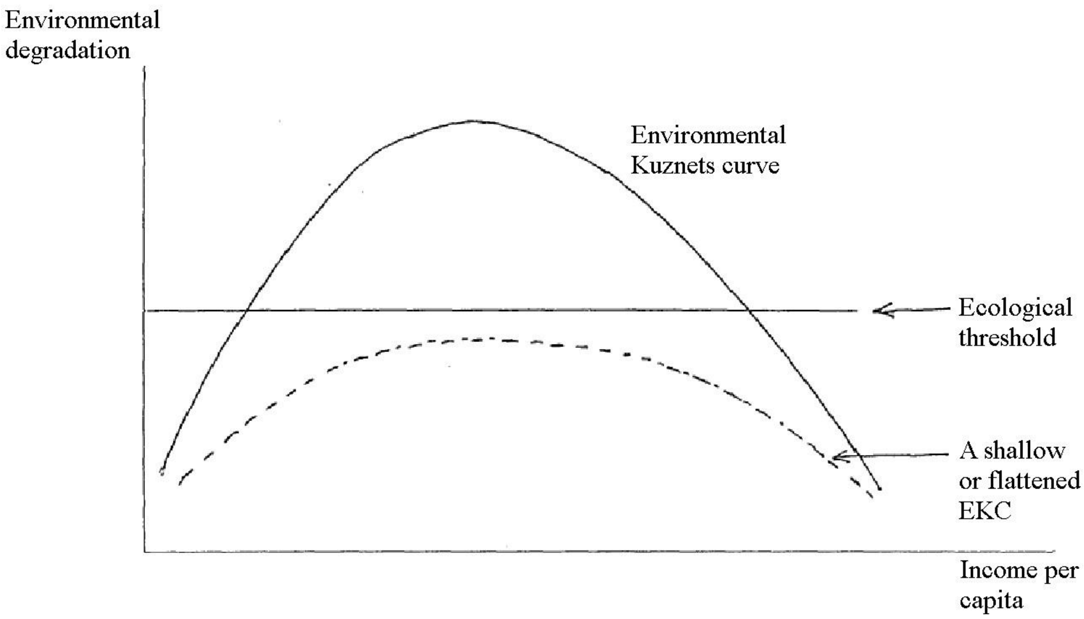

Figure 2-1: The Environmental Kuznets Curve (Panayotou, 1993, p.16)

The hypothesis of the EKC propounds that there exists an inverted U-shaped relationship between environment and income. It states that environmental degradation increases up to some point, which is the turning point, as the income increases. Yet, after the turning point, this degradation starts to decrease with an increase in income level (Akbostancı, Türüt-Aşık & Tunç, 2009, p.861). That is, the plotted graph between the income and the environmental degradation has an inverted U-shape as it can be seen from the Figure 1-1.

In fact, Kuznets (1955) found out the bell shaped curve in his study about the relationship between the income and income inequality. Due to similarity of the graphs, the name of environmental Kuznets curve was attained to relationship between income and environmental deterioration. Panayotou (1993) was the first researcher who called the diagram as the EKC (Dinda, 2004, p.434).

According to the EKC hypothesis, it is certain that if the hypothesis is affirmed by evidence, economic development will be environmentally beneficial in the long run, although it may heavily and irreversibly destroy the environment in the short run. The hypothesis is directly related to the ecological threshold which is underlined in the Figure 1-1 as well. At this point several questions may come to the scene as Panayotou (2003) elaborated them. Some of the questions are: which income level is the turning point? Up to the turning point, how much damage would be done to the environment and would those damages be irreversible? Can only a higher income level turn those damages in reverse or should it be supported by policies and regulations? All these questions draw attention to carrying capacity and ecological threshold. In other words, the necessity of the economic development for the sake of environmental degradation is argued in spite of empirical validity of the EKC.

Furthermore, Beckerman (1992) emphasized the requirement of economic growth in order to obtain environmental improvement. He supposed that enduring environmental degradation in the short run would bring environmental improvement in the long run through following the way of economic growth. Beckerman added, "The strong correlation between the incomes and the extent to which environmental protection measures are adopted demonstrates that in the long run, the surest way to improve your environment is to become rich" (as cited in Panayotou, 2003 p.2). Put another way, the EKC hypothesis frankly means that economic growth is the remedy for environmental deterioration rather than being a threat to the environment as many scholars claim (Stern, Common & Barbier, 1996, p.1152). Therefore, it is open to debate that whether the economic growth is a requirement for environmental improvement or it is the main reason for environmental degradation.

To clarify the questions stated above, before moving to literature about the EKC and its causes, it is better to take a look what lies behind the hypothesis itself. Apparently, the relationship between economic development and environment was discussed before conducting the empirical studies by economists was the origin of the hypothesis. The starting point of this relationship under the climate change issue is crucial for the future empirical studies about the EKC hypothesis as well. Therefore, having a brief glimpse about growth and environment nexus from environmentalists' point of view helps us to comprehend the EKC hypothesis thoroughly.

2.1. BEFORE THE EKC – GROWTH VS. ENVIRONMENT AND CLIMATE CHANGE IN INTERNATIONAL ARENA

The relationship between the economic growth and the environment has been highly controversial for a long time. Classical economics determine land, capital, and labor as the primary factors of production. Land is a physical capital supplying the essential natural resources that let every economic activity to take place. However, the exhaustibility of the natural resources triggers concerns about its possible impact on the capability of the production in order to sustain a positive consumption everlastingly (Tahvonen, 2000, p.4). Many researchers emphasize that the environment is under the pressure of economic growth. Basically, the acceleration of the economic activity means an increase in the production and the consumption together. So as to keep the economy grow, more resources are needed for production that will ultimately causes the resource depletion. Besides, more production and consumption eventually lead to generate wastes and pollution such as too much increase in air pollution, water pollution, and over accumulation of GHGs (Kaika & Zervas, 2013, p.1392). Moreover, this speed of economic activities would force the carrying capacity of the earth that is mentioned in previous part. As Li (2004) asserted that the rate of resource regeneration is exceeded by the rate of resource depletion and produced wastes are so far above the resilience capacity of the earth. That is why environment is under pressure with the economic development.

The very first step related to conservation of ecosystem was come forward with the publication of Silent Spring about the DDT’s impacts on birds and biological diversity by Rachel Carson in 1962. After this publication environmental concern was intensely expressed at the beginning of 1970s by some other researchers (Georgescu-Roegen, 1971; Meadows, Meadows, Randers & Behrens, 1972). Meadows et al. (1972) pointed out the finiteness of environmental resources and claimed the importance of the transition to steady-state economy. Otherwise, inevitable and irreversible ecological damages might occur. They brought the conclusion that the existing economic growth was harmful for the ecological balance of the earth due to the scarcity of the environmental resources; hence, it might be better to take into consideration of limits to growth to some extent. On the other hand, neoclassical economists were opponents of this idea. They pointed out the necessity of the economic growth for each and every country so limiting economic growth cannot be under discussion according to them.

This debate was carried to the global arena owing to perturbation of economic growth. If economic development is necessity for every nation, the evolution of global environmental concern is as vital as economic growth for all ecosystems on earth. The discussion of environmental issues in the international arena officially began with the Stockholm Conference then it was followed by Brundtland Report, Rio Conference and Kyoto Protocol with the pioneering role of the UN. At the same time, the empirical studies searching for the relationship between environment and economic growth bursted. Before scrutiny of the empirical researches about economic growth and the environment, we will go through the progress in environmental issues on global scale through main conferences and events in the history.

2.1.1. STOCKHOLM CONFERENCE

Stockholm hosted the very first UN Conference on the Human Environment in 1972. This conference was exclusive since it brought together politicians and scientist to discuss the concerns about global environmental issue for the first time (Seyfang, 2003, p.224). In fact, North, industrialized countries, wanted to bring local environmental issues such as air pollution to global agenda with Stockholm Conference in 1972; but, South, developing countries, did not really care about those environmental damages caused by developed countries because they were more interested in development issues as expected. Due to North's trouble about air pollution, the concern about the economic growth and the scarcity of environmental resources were explicitly highlighted in the first UN conference on Environment in Stockholm in 1972.

This conference is a milestone in the global environmental issues because environment and economic development was firstly linked in international arena even though the conference coincided with Cold War affecting the countries' participations to the conference. However, east-west situation pushed aside even the effect of the war since East Germany was not invited to the conference. Soviet bloc boycotted East Germany being ignored and did not attend as well. Nevertheless, 113 countries which was not a bad number compared to those times attended the Stockholm Conference, but only 2 of them sent the head of the country. It can be deduced that even if the purpose was discussing the environmental issues, Cold War and east-west politics dominated the conference atmosphere profoundly.

The conference had legal and institutional outcomes. Action Plan, principles, and Stockholm Declaration were the legal outcomes, whilst United Nations Environment Programme (UNEP hereafter) was the institutional result of Stockholm Conference. Hunter, Salzman & Zaelke (2002) pointed out that Stockholm Declaration was a visionary statement since it was to propose a human right to a better quality environment through integrating economic growth and environment, controlling the depletion of all kinds of resources, and reducing contamination. Besides, Nations' right to exploit their own resources pursuant to environmental policies was stated in Stockholm Declaration at article 21, which would bring a great leverage to the South in the future. The declaration was soft and was not legally binding; however, it was the groundwork of the future progresses, especially for the sustainable development concept.

2.1.2. BRUNTLAND REPORT

After the Stockholm Conference, the discussion about the relationship between environmental degradation and economic growth has accelerated. This paved the way for the concept of sustainable development. The clear definition of sustainable development can be found in Our Common Future (1987). According to this report usually called as Bruntland Report, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In other words, the inequality among generations and the depletion of environmental resources for the sake of economic development were emphasized in sustainable development concept. This notion leads to discuss and research about what kind of economic growth might be favorable for environment because it basically means that economic development should be directed by environmental and physical constraints (McCloskey, 1998, p154). Other than keeping the economic development under the environmental constraints, equitable distribution of wealth and efficient allocation of resources could be count as challenges with which sustainable development concept would confront (Hunter et al., 2002, p.184).

2.1.3. RIO CONFERENCE

With the emergence of sustainable development concept in 1987 then the foundations of IPCC in 1988, the global environmental problems were well shaped at

Rio Conference in 1992. Other than local air pollution problem just like in Stockholm, increasing average global temperature, which would eventually accelerate climate change, was the main theme of Rio Conference. To cope with climate change and its inevitable impacts, countries required to cooperatively consider decreasing global GHGs emissions which was clearly the main reason for the climate change. At this point, North needed to cooperate with South; hence, South had a great leverage in this conference. Moreover, there was neither cold war nor east-west conflict at the time of Rio Conference so the participation number was unsurprisingly higher. 178 countries, of which 115 sent the head of the countries, attended to the conference that might be a good indicator of given importance to Rio Conference.

The most noteworthy outcome of the conference was United Nations Framework Convention on Climate Change (UNFCCC hereafter) which would contribute to international environmental legislation through preparing annual Conference of Parties (COPs hereafter). The UNFCCC entered into force in 1994. Other than this institutional outcome of the conference, there were legal outcomes which were mainly Rio Declaration, Agenda 21, an agreement to create Commission on Sustainable Development, Convention on Biodiversity, and non-binding forestry principles. All of these legal consequences are again non-binding rules for states.

2.1.4. KYOTO PROTOCOL

GHGs, stimulating the global climate change, and their influence on the environment has been a growing problem. With this growing concern, Kyoto Protocol was adopted in the 3rd COP of UNFCC in Kyoto, Japan on 11 December 1997. Kyoto Protocol determines binding emission reduction targets for industrialized countries. In total, these countries are required to reduce an average 5% emission according to their level of emissions by the year 1990 for the five year first commitment period from 2008 to 2012 (UNFCCC, n.d.). The UNFCCC highlighted the crucial thing for the protocol is that it is only binding for developed states since they are mainly responsible for the current level of emissions, resulted from over 150 years of industrial activity. Hence, it put more burdens on developed countries depending on the common but differentiated responsibility which is one of the principles used for shaping international environmental law.

Although the protocol pays more attention on CO_2 emissions, it covers all GHGs. Von Stein (2008) stated that the ratification process was relatively slow so that the protocol entered into force in 2005 with the ratification of Russia. However, United States (US) and Australia have not yet ratified the protocol and their combined GHGs emissions compose nearly 26% of the world total GHGs emissions in 2008. The real reason beneath the disapproval of the US was that the protocol was not binding for developing nations such as China. The US clearly declared that they would not ratify the protocol as long as it does not binding for developing states as well.

In addition, Kyoto Protocol offers three innovative mechanisms which are Clean Development Mechanism, Joint Implementation, and Emission Trading in order to give support to developed countries for accomplishing their emission reduction targets (Lau, Lee & Mohamed, 2012, p.5281).

When the first commitment period was over, the Doha Amendment to the Kyoto Protocol was adopted in 2012 in order to determine second commitment period of protocol (UNFCCC, n.d.). The second commitment period covers the time period between 2013 and 2020. Results of the second commitment period will show where we are for mitigating the climate change. However, it is obvious that only Kyoto Protocol cannot tackle the climate change. Even though it is rather a big step in the global environmental issues, it is not enough. It should be broadened to touch on global solutions such as determining concrete investment plans for mitigation to climate change and adaptation for climate change, including specific developing countries whose emissions drastically augmenting the atmospheric concentrations, and supporting developing nations to restrict their emissions as well (United Nations, n.d.).

In sum, evolution of global environmental issues has been recently centered in climate change because it will possibly have irreversible and catastrophic impacts on mother earth. Increase in GHGs emissions, particularly CO_2 emissions, should be limited immediately so as to avoid these terrifying effects, which have already happened all over the world through droughts, forests fire, floods, etc. Although it is urgent to have legally binding regulations in this regard, the process is quite slow to generate global agreements because funding enforcements and implementing sanctions for the regulations remain problematic.

2.2. HISTORICAL REVIEW ABOUT THE EKC HYPOTHESIS

Even though the debate about the relationship between income and environmental deterioration has continued since 1970s, the real debate arrived at the scene when the first empirical study was conducted in 1991. Ironically, a path breaking study of Grossman & Krueger (1991), which is related to the North American Free Trade Agreement's impact on the environment, did not even give a reference to Club of Rome debate which was the discussion brought by Meadows et al. (1972). When taking into consideration that the EKC concept was developed by trade/development economists instead of environmental/natural resource economists, not even giving reference might not be so surprising (Carson, 2010, p.4). Frankly, the concerns about the restriction of the economic growth due to exhaustibility of natural resources were the initiative factor for the empirical researches. A highly influential study of Grossman & Krueger (1991) demonstrated that environmental damages could be reduced by the economic growth. They studied the relationship between Gross Domestic Product per capita (hereafter GDP per capita) as an income indicator and air pollutants which are SO_2 and Suspended Particulate Matter (SPM), as environmental indicators. Besides, trade was included in the study as an independent variable. Data covered various time periods for 42 countries. They analyzed this relationship through cubic form of GDP per capita then found out that the EKC exists. In other words, they concluded that the economic gains from trade would not become harmful to the environment rather it was expected.

Independently from Grossman & Krueger's paper, there are two other base studies about the EKC, which are papers of Shafik & Bandyopadhyay (1992) and Panayotou (1993). They also found out the similar results, which supporting economic growth so as to overcome the problem of environmental degradation.

Shafik & Bandyopadhyay (1992) studied on 10 different environmental indicators for 149 countries between 1960 and 1990. Log-linear, log-quadratic, and log-cubic polynomial functional forms of GDP per capita were used to estimate the EKC. While two air pollutants confirmed the validity of the EKC hypothesis, remaining indicators did not. These ambiguous results were clear signs of complex relationship between growth and environment in contrast to Grossman & Krueger's findings.

Panayotou (1993) estimated the EKC for 4 different environmental indicators along with GDP was in nominal value in the late 1980s. Cross-sectional data estimation techniques with log-quadratic and translog functions were used in the analyses. The EKC were valid for all the estimated curves. Moreover, Panayotou (1993) proposed that the reduction in environmental damage might be possible with the help of higher levels of income because economic growth could be a powerful way so as to improve environmental quality especially in developing countries.

After these cornerstone studies, there have been growing literature about the EKC. Many studies in this growing literature of the EKC depend on parametric approach. In other words, polynomial functions are used in empirical analyses. For instance, Holtz-Eakin & Selden (1992) examined the relationship between per capita CO_2 emissions and GDP per capita for 130 countries during the time period between 1951 and 1986 through parametric specifications and panel data estimation techniques. They found out inverted U-shape for quadratic specifications, whilst N-shape curve was detected for cubic formulation.

Kaufmann, Davidsdottir, Garnham & Pauly (1998) investigated the reduced form relationship between SO_2 concentration and per capita GDP for 23 countries the years between 1974 and 1989 through panel data estimation techniques. They acquired the inverted U-shape relationship, whereas they obtained U-shape relationship when they added more variables in the empirical analysis. Hence, other than income and environmental impact, different variables are started to taken into account.

Lately, semi-parametric and nonparametric techniques have been appealed to examine the validity of the EKC (Azomahou, Laisney & Van, 2006, p.1351). To illustrate, Taskin & Zaim (2000) used nonparametric production frontier techniques for the investigation of the EKC. They used environmental efficiency index as a dependent variable based on the cross sectional data for CO_2 emissions and GDP per capita as an independent variable for the time horizon between 1975 and 1990. They executed the analysis each 52 countries then they detected an inverted U-shape for the countries having more than $5000 GDP per capita.

Millimet, List & Stengos (2003) utilized semiparametric partially linear models to investigate the validity of the EKC for 48 US states between 1929 and 1994. They found out the inverted U-shape relationship between SO_2, NO_x, and GDP per capita.

While the empirical techniques have been flourishing to investigate the relationship between income and environmental impacts, other branch of the EKC studies detecting the relationship between economic development and energy use has been growing (Bölük & Mert, 2014, p.440). Most of these studies check for the causality relationship between energy consumption and economic output through time series analysis usually. After that these two branches were combined and energy use, environment, and economic growth nexus was shaped as another area of study.

Apart from the review of some studies in the literature, some studies in the literature can be found in Appendix A. There was not a consensus among even the earliest studies in the EKC literature. The published literature underlines different relationships together with a wide range of turning point estimates. Empirical studies are conducted using different econometric techniques, variety of indicators, a wide range of geographical locations, and different time horizons. These conditions will be detailed in Chapter 4. Before move on that chapter to elaborate those conditions, we will focus on the underlying reasons of the EKC.

CHAPTER 3

CONCEPTUAL BACKGROUND OF THE EKC

There are several factors affecting the relationship between income and environmental quality; put another way, the EKC is affected by several factors. These factors might have microeconomics, macroeconomics, and/or political economics point of views. Four broad forces give evidence about the existing of the EKC. One possibility is households tend to choose better environmental quality, as income increases. This will be followed by various production and consumption patterns comply with public action. The second one is the change in the product mix. This explains the shift in the economic activities from an agro-based economy to a heavily-polluted production sector then to a service sector. Trade is the third possibility. Countries are prone to shift their pollution to other countries when they have higher GDP level because they have already transformed their product mix into service sector. Lastly, environmental policy and institutionalization are factors may have contributions to explain the EKC pattern since rich countries have both more strict environmental regulation and higher institutional capacity. In the following parts, these factors are explained in detail.

3.1. INCOME ELASTICITY OF DEMAND FOR ENVIRONMENTAL QUALITY AND CONSUMER PREFERENCES

From the microeconomics point of view, both income elasticity of the demand for environmental quality and consumer preferences are partial agents effecting the existence of the EKC. The main reason for this partial explanation is that income-pollution nexus is macroeconomics subject, while consumer preferences and income elasticity demand for environmental quality have microeconomics foundations. However, it is still important to examine the change in demand for environmental quality and consumer preferences as the income changes.

Depending on the income change, it is expected that people's demands for environmental resources varies as well as their demands for every good (Yandle, Vijayaraghavan & Bhattarai, 2002, p.6). This variation in demand for environmental quality is simply called income elasticity of environmental quality demand.

$$\eta = \frac{(\Delta \mathrm{E})\%}{(\Delta Y)\%} = \frac{\partial E}{\partial Y}\frac{Y}{E}$$

The modified elasticity equation for the environment derived from Pearce (2003) and Kaika & Zervas (2013) is exhibited above. According to equation, *Y* is income and *E* is the quantity of environmental good demanded. Their proportional change gives us η, the income elasticity of environmental quality demand. In general concept, if $|\eta| < 1$, E is a normal good; and if $|\eta| >1$, E is a luxury good. Besides, McConnell (1997) clarified that there is no special meaning if if $|\eta| = 1$.

It is common among most authors that clean environment and preservation are accepted as 'luxury goods' (Dinda, 2004, p. 435). Luxury goods concept is actually based on the idea that the environmental quality gains importance as people become richer, hence the concept is directly related to the income level. In other words, the income elasticity of demand for environmental quality is greater than zero, possibly even greater than one, or as income grows environmental concern rises as well, perhaps even more than proportionally so (Beckerman, 1992; World Bank, 1992). It can be deduced that there is a clear link between per capita income and environmental concern of the people because their income level affects their demand for environmental improvements. This link is a distinct sign of EKC. Nevertheless, the assumption of accepting environmental quality as a luxury good is an intuitive reaction among economists since there are empirical studies about not supporting this (Kristrom & Riera, 1996, p.45). Therefore, it may indicate that every person's demand for a particular good may not change in the same direction as the income increases. At this point, consumer preferences gain more importance.

People's consumption choice is referred as consumer preferences in the literature of the microeconomics. As people earn higher income, their living standards tend to change as well. Nahman & Antorobus (2005) stated that the richer people become, the more they consume. Although people with higher income level consume more, it does not necessarily mean that their impacts on environment are devastating since they tend to give more attention to environmental problems and demand for better environment. For instance, they prefer to consume environmentally friendly and healthy products (Bo, 2011, p.1323). In other words, there is a direct relation between consumption of pollution intensive goods and per capita income (Nahman & Antorobus, 2005, p.115). Hence, it is significant to measure changes in the consumer preferences regarding to environmental quality when the income alters although it is not easy to measure. Willingness to Pay (WTP hereafter) may be a good way to measure consumer preferences for environmentally friendly goods.

$$\omega = \frac{\partial WTP}{\partial Y} \frac{Y}{WTP}$$

The equation above for income elasticity of willingness to pay shows the change in willingness to pay for environmental quality in response to a change in income (Pearce, 2003, p.3). The potential willingness to abandon the existing consumption pattern in order to attain better environmental quality can be figuratively defined as a purchase of more environmental quality (Roca, 2002, p.10). However, it is better to bear in mind that environmental quality is a public good for most of the cases. In this sense, this public problem of environmental degradation will not solely be solved with the economic growth.

After all, it is obvious that the change in the consumer preferences with higher income eventually leads to structural changes in economy, which will be detailed in the following section, which is called diminishing environmental deterioration. Moreover, people with higher income force upon the environmental protection and legislation while they change their living style through spending more on environmentally friendly products because local pressure is significant to shape environmental policy (Dinda, 2004, p. 435 and Kristrom & Riera, 1996, p.45). As Stokey (1998) stated that the severe environmental regulations can be resulted from the income elasticity of demand for better environmental quality. That is, this concept is directly or indirectly connected to other factors explaining the reasons of the existence of the EKC. Yet, examining not only the consumer preferences but also the income elasticity of demand for environmental quality are rather complicated and difficult to deal with. For example, aforementioned appropriate and expected preferences may lead to reach the validity of the EKC hypothesis (Plassman & Khanna, 2006, p.632). On the other hand, this tendency is not guaranteed because the shift in consumers' preferences may be based on different time and spatial circumstances. Thus, although these subjects are difficult to examine according to microeconomic implications, they may still bring good explanations for the EKC because there is an undeniable link between increasing income and the people's attitude towards the environment.

3.2. SCALE, COMPOSITION, AND TECHNIQUE EFFECT

As income-pollution relationship is macroeconomics subject, degree of economic activities from macroeconomics perspective may have an impact on environment. Grossman & Krueger (1991) claimed that environmental quality is affected by the economic activity through three ways which are scale effect, composition effect, and technique effect.

3.2.1. SCALE EFFECT

As the economic activities accelerate, more outputs are produced. So as to enhance the output level, simply, more inputs are required. More inputs actually mean that more natural resources are consumed in the production process. The exploitation of natural resources in this way plainly damages environment. Likely, more outputs also refers to more emissions and wastes that deteriorate environmental quality as well (Dinda, 2004, p.425). Thereby, acceleration of economic activities causes the destruction of environment through both ways which are the overuse of natural resources and the release of emissions and wastes to the environment. In other words, *ceteris paribus*, meaning no change in the structure or technology of the economy, an increase in pollution, depletion of natural resources, and other environmental drawbacks are resulted from the growth in the scale of the economy (Stern, 2004, p.3; Panayotou, 2003, p.17). This is so called the scale effect.

3.2.2. COMPOSITION EFFECT

It is indicated in the previous part that production activities produce wastes and emissions generally referred as pollution. Stern (2004) stated that different sectors have different pollution levels such as heavy industrial sectors create more environmental degradation and service sectors produce less environmental degradation. That is, the composition of the economic activity is significant for environmental quality. During the industrial revolution, structure of the economy shifted from rural and agricultural to urban and industrial, respectively. But, this structural change did not stuck in the industrial economy. Thanks to economic development, structure of the economy has transformed once again because it has changed from energy intensive sector to knowledge based technology intensive sector and service sector (Dinda, 2005, p.435). In other words, cleaner activities have been steadily increased as economic grows that leads to produce less pollution and use less natural resources. This is so called a composition effect. Moreover, this type of transformation exists for different level of incomes. For instance, a change from agricultural economy to industrial one at lower income countries clearly contributes to increase pollution intensity. After all, an alteration from industry to service sector, helping to reduce pollution intensity, can be observed at higher income level. It is obvious that the composition effect is an inverted-U shape function of GDP (Panayotou, 2003, p.17).

3.2.3. TECHNIQUE EFFECT

Increase in both technological advances and R&D have crucial impacts on production process. Firstly, enhancing productivity with the technology causes to use less polluting inputs per unit of output (Stern, 2004, p.4). That is, environmental resources are used effectively in the production. Secondly, technology used for the production is replaced by cleaner or environmentally friendly ones with the help of technological advances. Consequently, less pollution is released to the environment by product of outputs. However, technological advances can be encouraged by spending more on them that may be likely for richer countries because they have enough money to encourage technological researches. In other words, more productive and cleaner technology can be possible by economic growth, which brings about more spending on them.

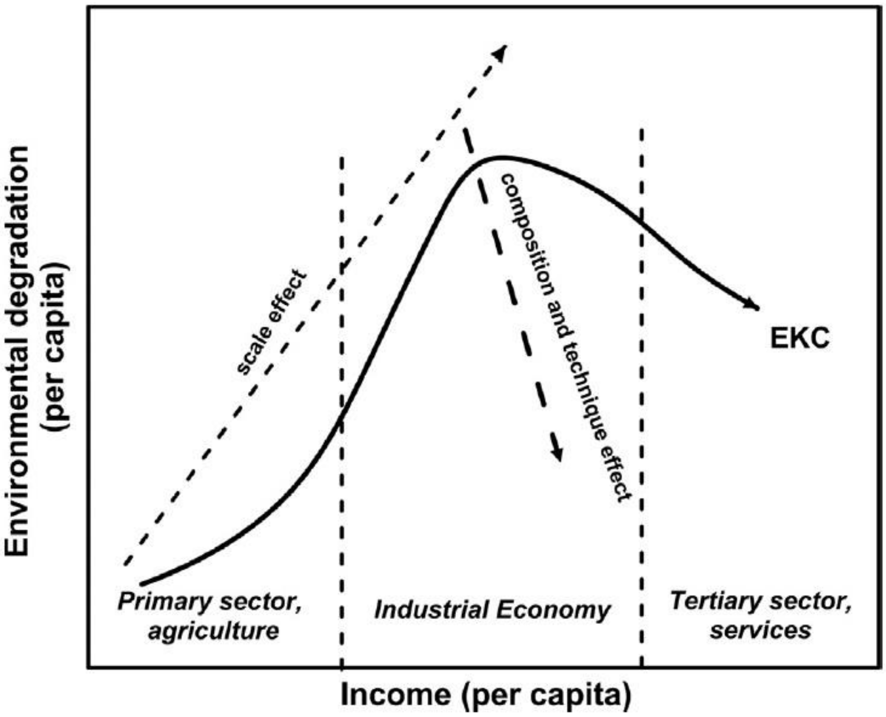

Figure 3-1: The Impact of Scale, Composition and techniques effects on the EKC (Kaika & Zervas, 2013, p.1394)

It can be understood from the explanations of three different effects, they have different impacts on environmental degradation. The scale effect increases environmental degradation, but the technique effect decreases it. The composition effect may influences the pollution level in two different ways with respect to GDP per capita or income level. Figure 3-1 reveals the relationship between income and environmental degradation, which is the EKC, under these three effects.

Transformation of economic activities with respect to income per capita level can be seen clearly in the graph.

Stern (2003) summarized these three effects, mentioned above, as proximal factors. Proximal factors consist of the scale effect, changes in input mix (e.g. using environmentally friendly inputs instead of environmentally damaging ones), changes in output mix (e.g. shift from heavy manufacturing industry to knowledge based and service sectors), and technological advances, causing cleaner production processes (producing less emissions per unit of input used) and production efficiency (using less inputs per unit of output). Therefore, it is expected that on the first part of the EKC, until the turning point, the scale effect is the dominant effect, while the technique and composition effects dominate the scale effect on the declining part of the graph, after the turning point (Akbostancı et al., 2009, p.862). In sum, if the scale effect is suppressed by composition and technique effects, this may help to observe an inverted U-shape between income and environmental degradation, the EKC.

3.3. INTERNATIONAL TRADE

International trade is one of the most significant macroeconomics determinants that can clarify the EKC. All other factors constant, trade basically causes to increase in the size of economy, which aforementioned results in environmental deterioration. Thereby, it can be easily deducted that environmental damage is driven by international trade. Although many researchers claim that trade is not the core factor of environmental degradation, trade openness seems to have the ambiguous effects on environment because it not only triggers to decline pollution as an indirect effect with the rise in income resulted from trade but also to increase it (Dinda, 2004, p.436). As a result, free trade is partly related to aforementioned scale, technique, and composition effects.

It is stated above that scale effect is the reason to reduce environmental quality through increasing the size of the economy. Liberalized trade encourages this through increased market access. But, in the end, trade causes to rise in income. Technique effect is also accompanied by free trade because it pulls the income level of the countries up. Consumers with higher income are expected to demand better environmental quality that would help to enact more severe environmental regulations and use environmentally friendly technologies (Cole, 2004, p.72). Apart from scale and technique effects, the composition effect is triggered by trade openness as well. The composition effect denotes the shift in the economic structure. However, this shift happens from developed countries to developing ones through the liberalized trade. Kearsly & Riddel (2010) claim that whilst developed countries specialize in service sector and in light manufacturing, developing ones somehow oblige to focus on dirty manufacturing in the sense that their comparative advantage. At this point, developing countries' low environmental standards create their comparative advantage (Dinda, 2004, p.437). This distinction between countries due to change in their economic structure creates composition effect which is attributed to Pollution Haven Hypothesis (hereafter PHH).

3.3.1. POLLUTION HEAVEN HYPOTHESIS (PHH)

As stated above, PHH is strongly related to the composition effect because both of them refer to the shift in the economic structure. Liberalized trade procures the specialization of production type with respect to countries' comparative advantage. According to Cole (2004), PHH express that industry types of developed and developing economies; such as heavy manufacturing, light manufacturing, services are differentiated by their environmental regulations. If the countries' environmental regulation does not allow them to produce specific goods and/or services due to produced pollution or wastes in production, those countries import the specified products instead of producing it. That is, developed countries shift their dirty production which is forbidden by the environmental regulation to developing ones having less strict environmental regulations. Hence, a considerable amount of pollution, which is caused by pollution intensive industries, can be avoided by the developed countries while that amount is received by developing states.

Frankly, the reason for an obvious rise in environmental quality at higher levels of income is a change in the way of international free trade and international movements in pollution-intensive industries (Nahman & Antrobus, 2005, p.112). Nahman & Antrobus (2005) also briefly explain the steps for PHH. Consumers which have higher levels of income in developed countries demand for a better environmental condition. This triggers the more severe environmental regulations in those countries, which result in shifting heavy manufacturing industries abroad. This shift leads to increase the environmental quality for richer countries because they import pollution – intensive goods instead of producing them, while this pollution is gotten by poor countries; it does not totally disappear. Thus, the EKC may be valid for developed countries due to PHH because they decrease environmental deterioration within the countries' borders after relocating the productions of heavy polluted goods. However, there would not be global decline in environmental degradation since dirty industries continue to produce in another country. They simply neither stop depleting natural resources nor stop producing wastes. It is a kind of an illusion of improvement in environmental deterioration. Therefore, as Dinda (2004) remarks that if heavy polluters move to countries with less strict environmental regulations, lower trade barriers can profoundly damage to the environment.

3.4. REGULATIONS AND POLICY IMPLICATIONS

Environmental regulation is the factor which is based on the political economics thoroughly affecting environmental quality. It is clear that countries having tight and strict regulation are tend to enjoy better environmental quality because governments may use sanctions on individuals and firms to attain pollution abatement through those rules and norms. Hence, why do all countries not have tighter environmental regulations to prevent environmental degradation can be the question to be asked. This question leads to think that there should be some limitations to have environmental regulations.

At the first place, as Cole & Neumayer (2005) stated that the wealth of the countries is one of the crucial agents to determine severe environmental acts. This relationship between income and environmental regulation is highlighted in the study of

Dasgupta, Mody, Roy & Wheeler (2001). They empirically investigated for the correlation between pollution regulation and per capita income in 31 countries. The Figure 3-2 from their study evidently reveals that environmental regulation increase as the per capita income increases. As a consequence, for those 31 countries, income level is a significant determinant for having rigid environmental acts.

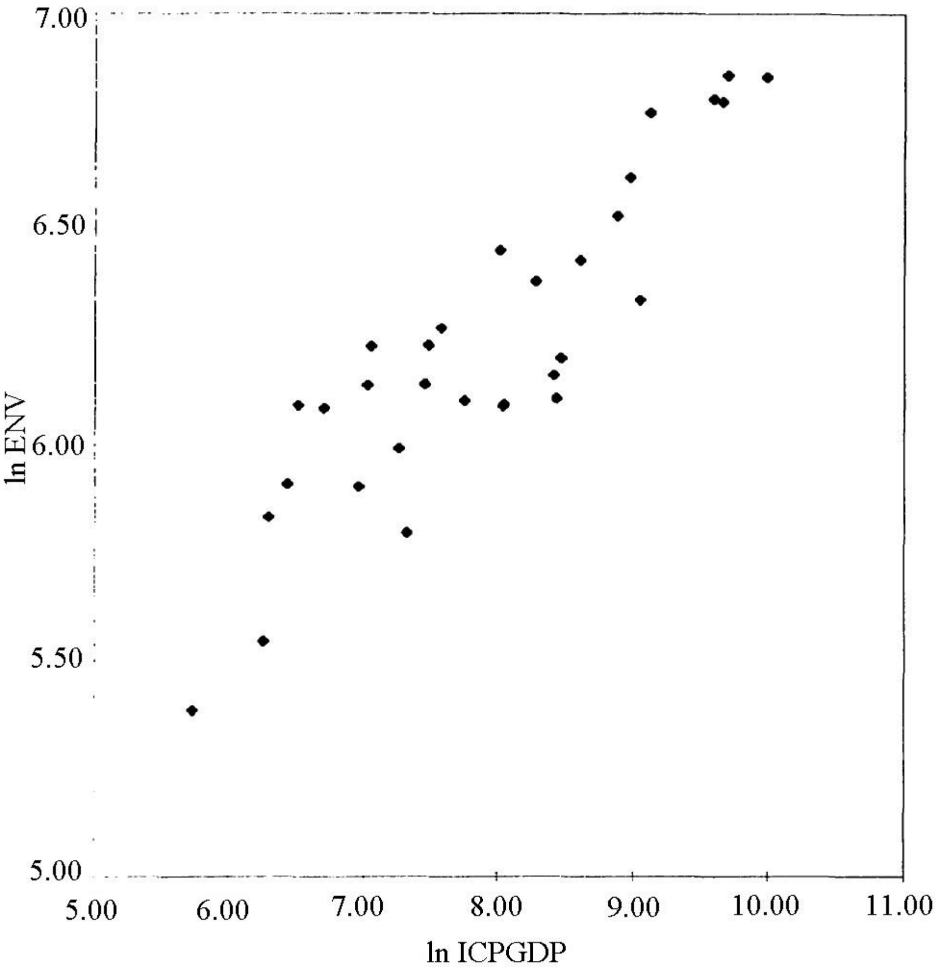

Figure 3-2: Relationship between per capita income and environmental regulation (Dasgupta et al., 2001, p.15)

Morever, Dasgupta, Laplante, Wang & Wheeler (2002) pointed three main reasons out why lower level income countries have less rigid environmental law than higher level income ones. First of all, health and education are acknowledged as fundamental needs for society thereof, investing in these both elements have urgency than environmental quality. Secondly, poorer countries may not provide sufficient budgets and technical supports in order to implement and to monitor the environmental regulations. Enacting a law obliges to implement and to monitor it as well. Besides, these stages need budgets, experts, and influential governmental institutions. It is prominent that developing states typically have less effective, more corrupt, and weaker governmental institutions comparing to developed ones. Hence, institutional capacity is other key factor for having strict environmental regulations. Therefore, it is more likely for developed countries to have tighter environmental regulations. In addition to these, people with higher income are prone to demand better environmental quality since the main factor, which affects people's approach to environmental legislation, is notably the income (Stokey, 1998, p.3). As aforementioned reasons ascertained that income level and environmental regulations have positive relationship.

However, Mody, Roy, Wheeler & Dasgupta (1995) signified the importance of political and institutional factors effecting the environmental policy and performance. Freedom of information and education, efficient regulatory systems, and economy with secure property rights leading to longer planning are some of the political and institutional drivers defining the environmental policy. According to Barrett & Graddy (2000), there is an expected policy response between the governments and their citizens. As countries benefit from economic growth and turn out to be richer, citizens are expected to demand better environmental quality, which is the non – material side of their life standards. However, this perception demonstrates that the nations' economic development is not the only determinant for the environmental quality. It is partially affected from:

"... citizens being able to acquire information about the quality of their environment, to assemble and organize, and to give voice to their preferences for environmental quality; and on governments having an incentive to satisfy these preferences by changing policy, perhaps the most powerful incentive being the desire to get elected or re-elected. " (Barrett & Graddy, 2000, p.434). In other words, civil and political freedoms are important for environmental regulations other than the income level of citizens. Citizens can compel the government to have environmental acts if they have enough freedom and having freedom does not solely depend on the prosperity of nations. At this point, environmental awareness is significant to enforce the policy institutions for environmental regulations. There should be other factor other than income influencing the environmental policy. In sum, although income level profoundly affects the environmental regulation process, it may not be the only determinant for better and stricter environmental regulations.

After the conceptual background, it may be a good reminder to give precise definition of the EKC from Stern et al. (1996)'s study:

"At low levels of development both the quantity and intensity of environmental degradation is limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As economic development accelerates with the intensification of agriculture and other resource extraction and the takeoff of industrialization, the rates of resource regeneration, and waste generation increase in quantity and toxicity. At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, expenditures, result in levelling off and gradual decline of environmental degradation." (p.1151). This definition covers all aforementioned factors affecting the existence of the EKC. Obviously, income level is the main trigger for reversing the curve from increasing to decreasing trend of environmental degradation. Nevertheless, it may not be necessity to have higher level of income so as to generate environmental awareness in a society at all.

CHAPTER 4

VARIABLE MEASUREMENTS OF THE EKC

There are many theoretical and empirical studies investigating the EKC in the literature. Empirical studies use different environmental and economic indicators, various econometric techniques, different geographical locations and time intervals. The selection of variables, econometric techniques, geographical locations and time periods entirely affect the results of the studies so this choice is crucial. In this part, these different economic and environmental indicators will be elaborated.

While doing empirical study for the relationship between income and environmental quality, different indicators are selected depending on the focus point of the research. It is obvious that GDP per capita is assumed as primary economic indicator for the EKC studies because it is itself the core of the hypothesis. As Panayotou (2003) expressed, some of the studies use income data through converting them into purchasing power parity (PPP) or use them at market exchange rates. Yet, not solely GDP per capita is used as an explanatory variable in the econometric analysis. Other independent variables are added to analysis so as to get more accurate relationship between income and pollution as well as measure different parameters (Wong & Lewis, 2013, p.3). Some of the independent variables can be listed as energy use, trade, population density, education and literacy measures, democracy and civil liberties, the share of industry as part of a country's output urbanization rates, income distribution, income inequality, energy efficiency etc.

What is more, the study area of the EKC is essential for the analysis because it changes the sample size and the sample feature. As Jordan (2012) specifies that there exist cross – country scale, country scale, region scale, city scale, lake/watershed scale, and firm, household and individual scale studies in the literature of the EKC. As some of the EKC studies imply that choosing local area for study is more feasible than global wide because local pollutants have more tendencies to exhibit an inverted U-shape relationship with income. Stern (2004) stated that local effects are easily internalized within a distinct region or economy since those effects trigger policy implications in that region. It is more difficult to apply similar environmental policies worldwide to limit externalized environmental problem. For this reason, studying regional or local level looks more feasible rather than global scale. However, if the CO_2 emissions accepted as global pollutants are used as environmental indicators in the analysis, focusing on regional or local area is not really feasible because emissions are distributed throughout the atmosphere. In fact, they influence whole earth rather than a specific region (Waldhoff, 2007, p.46). At this point, studying cross-country makes more sense for the global pollutions like CO_2 emissions. Therefore, the study areas can be decided depending on pollutants as well as data availability.

In the past decades, some selected pollutants were used in studies of the EKC. Whereas, economists came to the point that environmental quality could be used in studies of the EKC since the hypothesis is consistent with the perception that people are prone to spend more on the quality of the environment when their income increase (Arrow et al., 1995, p.520). Hence, environmental quality indicators, dependent variables, used in the studies were sort of extended based usually upon the pollution types. According to this, the empirical works in the EKC literature can be classified into four main categories which are air quality, water quality, CO_2 emissions, and other environmental indicators.

4.1. AIR QUALITY

Air pollution is one of the well-known environmental problems because it directly is harmful for people’s health as Dinda (2004) inferred. This situation makes air quality even more vital. There are plenty of studies in the EKC literature discussed about the relationship between air quality and per capita income. SO_2, SPM, Carbon Monoxide (CO), Nitrogen Oxides (NO_x) are commonly used air quality indicators in the literature (Grossman & Krueger, 1991, 1995; Panayotou, 1993; Selden & Song, 1994; Cole et al., 1997, De Bruyn, 1997; Kaufmann et al. 1998; Harbaugh et al., 2001; Millimet et al., 2003; Perman & Stern, 2003; Akbostancı et al. 2007). The amount of these chemicals should clearly be less to have better air quality. SO_2 is the most commonly used air quality indicator because it is mainly released from human sourced activities like combusting fossil fuels in the vehicles. Stern (2004) stated that local air pollutants like SO_2 are usually anticipated to follow the path of inverted U-shape when income rises. Hence, it can be concluded that SO_2 became the main air pollution indicator for the EKC hypothesis.

Although there are many studies, which particularly focus on SO_2 concentrations, estimating the EKC, not all of them support the hypothesis. The results of the studies reveal ambiguous results can be seen in the Appendix A.

4.2. WATER QUALITY

Just like air pollution, water pollution is one of the environmental degradation on earth. Water quality indicators can be classified into three main parts, which are namely heavy metals, pathogenic contamination and/or microbiology concentration, and state of oxygen regime (Dinda, 2004, p.441; Grossman & Krueger, 1995, p.357; Wong & Lewis, 2013, p.416).

Firstly, amount of heavy metals in water is significant for determining water quality. This amount can be measured by looking at the level of cadmium, lead, mercury, DDT, phenols, nickel, arsenic, and toxic chemicals in water. Industry, agriculture, and mining activities release these metals into water. Then they are accumulated at the bottom sediment of water that can be found in drinking water (Grossman & Krueger, 1995, p.359). They can also reach human body through bioaccumulation in fishes. As a result, their existence may cause different health problem in human other than creating some ecosystem damage.

Secondly, water pollution is partially derived from pathogenic contamination and/or microbiology concentration. Fecal and total coliforms, Chlorophyll A can be checked to assess water quality in terms of pathogenic concentration. Pathogens are not directly resulted from economic activity, but they are the result of releasing sewage into the rivers without necessary treatment. Grossman & Krueger (1995) stated that they may cause fatal disease like cholera, dysentery, hepatitis etc.

Lastly and more importantly, the state of oxygen regime is an indicator for water quality because it affects ecosystem as a whole. Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen (COD) are taken into account to determine the oxygen regime of the water. Although DO shows directly water quality, BOD and COD express available pollutants that ultimately resulted in oxygen loss. It can be concluded that both COD and BOD are prone to negatively correlated with DO concentration in the water (Vincent, 1997, p.426).

Studies for water quality indicators produced even more ambiguous results than ones with air quality indicators. Some of the studies like Cole (2004) found the inverted U-shape curve, whiles others reached different graph shapes like Wong & Lewis discovered N-shape curve. Check the Appendix A for detailed literature review.

4.3. CO_2 EMISSIONS

Recently, many studies in the EKC literature focus more on to examine the relationship between economic growth and CO_2 emissions, which is not the most abundant but the most significant GHGs, due to the arouse in the concerns for the global climate change (Kaika & Zervas, 2013, p.1400; Huang et al., 2008, p.340). As Borghesi (1999), Friedl & Getzner (2003), and Sharma (2011) asserted that CO_2 contributes climate change more than other GHGs since combustion of fossil fuels cause to release huge amount of CO_2 emissions; hence, this situation makes CO_2 emissions crucial. Another reason for focusing attention on CO_2 is that for time series, which are longer than any other pollution indicator, data on CO_2 emissions are available (Borghesi, 1999, p.8). Moreover, the impact of the economic growth on the CO_2 emissions is another subject to debate that has been driven empirical studies to focus more on estimating the relationship between CO_2 emissions and economic development.

Our study also focuses on the relationship between CO_2 emissions and the economic growth; hence, details about the EKC literature in this regard will be explained in part 4.5.

4.4. OTHER VARIABLES

Although early EKC literature has common usage of CO_2 emissions, air and water quality indicators, different environmental indicators such as deforestation, municipal solid waste, access to safe drinking water, and ecological foot print, different environmental indexes are frequently used in the recent studies as well. They also give different results for validating the EKC. Summary of studies using these different variables other than air pollutants, water pollutants, and CO_2 emissions are exhibited in Appendix A.

4.5. REVIEW OF LITERATURE ON THE EKC STUDIES FOR CO_2 EMISSIONS

CO_2 is just one of the gases composing atmosphere and it is measured in particle per million (ppm). The concentration of the gases is nearly 0.033% in the atmosphere and corresponds almost 330ppm. However, its release in the atmosphere has been rising day by day due to human drivers on earth such as the combustion of fossil fuels, cement production, and deforestation. Recently, it reached the level of 400 ppm. As it is stated before, this immense increase in CO_2 emission level triggers global climate change which is a growing concern all over the world. That is why studying about CO_2 emission is significant.

In the EKC literature, there are plenty of studies estimating the relationship between income and CO_2 emissions. In fact, one of the cornerstone studies Shafik & Bandyopadhyay's working paper was the first one in this regard. Some of studies use different explanatory variables apart from GDP per capita, select various geographical locations and time periods, and apply a range of econometric techniques such as time series, cross-sectional, and panel data estimation techniques. The Table 4-1 below demonstrates the main studies in the EKC literature estimated by using CO_2 emissions as an environmental indicator. Authors and publication year, economic indicators, CO_2 emissions as an environmental indicator, econometric techniques, geographical locations, time periods, and the results related to corresponding studies can be found in the Table 4-1.

Table 4-1: The literature reviews of selected EKC studies for CO_2 emissions. (Choi, 2012, p.6-11; He, 2007, p.37-39; Panayotou, 2003, p.44-47; Wong & Lewis, 2013; Kaika & Zervas, 2013, p.1398-1400)

CO_2 EMISSIONS					
Authors & Publication Year	**Environmental Indicators**	**Economic Indicators & Other Variables**	**Regions & Periods**	**Econometric Technique**	**Results**
Shafik & Bandyopad-hyay (1992)	Deforestation; per capita(cap) CO_2 emissions; Water (DO and fecal coliforms)	GDP per cap, a time trend	149 countries, 1961-1986	Panel data, Log, Quadratic, Cubic, Fixed effect (FE) model	CO_2; monotonically increasing
Holtz-Eakin & Selden (1992)	per cap CO_2 emissions	GDP per cap	130 countries: 1951-1986	Panel data, Log, Quadratic, Cubic; FE model	Quadratic inverted-U shape, Cubic N-normal
Moomaw & Unruh (1997)	per cap CO_2 emissions	GDP per cap	16 industrial OECD countries; 1950-1992	Panel data, quadratic and cubic, FE and Pooled Ordinary Least Square (OLS)	Inverted U-shape for quadratic, N-shape for cubic
De Bruyn, van den Bergh & Opschoor (1998)	per cap CO_2 emissions, Nitrious Oxide (Nox), Sulfure Dioxide (SO_2)	GDP per cap, structural changes, technology, population density	Netherlands, West Germany, UK, and USA; 1960-1993	Time series, log, decomposition analysis	Monotonically increasing
Galeotti & Lanza (1999)	per cap CO_2 emissions	GDP per cap	110 countries: 1971-1996	Log, Gamma and Weibull functions	Inverted U-shape (All countries, Non-OECD and OECD countries)

Table 4.1: Continued

Ravallion, Heil & Jalan (2000)	per cap CO_2	average per cap GDP, population, time trend, GINI coefficient (income inequality)	42 countries; 1975-1992	Panel data, level and log, quadratic, cubic; FE and Pooled OLS	Pooled OLS is better; Cubic: insignificant, Quadratic: monotonically decrease as income inequality grows
Borghesi (2000)	CO_2 per cap	GDP per cap in PPP, population density, GINI coefficient	126 countries; 1988-1995	Panel data, log and level, linear, quadratic, cubic; FE	Monotonically increase, CO_2 emissions decrease slightly as inequality grows
Vollebergh & Dijkgraaf (2001)	CO_2 per cap	GDP per cap, energy consumption per cap	24 OECD countries; 1960-1997	Panel data, time series, log, cubic; FE and Seemingly Unrelated Regressions (SUR)	N shape for panel data; N shape for 5 countries in time series data
Cole (2004)	CO_2 per cap, 9 more air pollutants and water pollutants	GDP per cap, share of manufacturing in GNP, share of pollution intensive exports and imports in total exports and imports, trade intensity	21 OECD countries; 1980-1987	Panel data, log, cubic (quadratc for some of the equations); Generalized Least Square (GLS) with Random Effect (RE) and FE Models	Inverted U-shape for CO_2, inverted U-shape and inverted N-shape for other pollutants
Dinda & Coondoo (2006)	per cap CO_2 emissions	GDP per cap and a time trend	88 countries: 1960-1990	Panel data, log; Cointegration test, Error Correction Test (ECM)	Bi-directional relationship
Akbostancı, Türüt-Aşık & Tunç (2009)	SO_2, SPM, CO_2	GDP per cap, population density	Turkey; 1968–2003 - time series model; 1992-2001 - panel data model (provinces base)	time series-Johansen cointegration, panel data-GLS, level and log; cubic	N-shape for SO_2 and SPM; monotonically increasing for CO_2

Table 4.1: Continued

Dutt, K. (2009)	per cap CO_2 emissions	GDP per capita, Governance, political institutions, socioeconomic conditions, population density, education	124 countries 1960-2002	Panel Data, Quadratic; Robust OLS, Fixed Effect Model	Linear between 1960-1980; Inverted U-shape between 1984-2002
Narayan & Narayan (2011)	per cap CO_2 emissions	Real GDP	43 developing countries; 1980-2004	Panel data; Panel Cointegration	Inverted U-shape in Middle Eastern and South Asia panels
Jayanthaku-maran, Verma & Liu (2012)	per cap CO_2 emissions	GDP per cap, energy consumption per cap, trade intensity, manufacturing value added	China and India	Time series, log, cointegration and ARDL methodology	Structural breaks are detected
Jobert, Karanfil & Tykhonenko (2012)	per cap CO_2 emissions	Real per cap GDP and per cap energy consumption	55 countries; 1970-2008	Bayesian shrinkage estimators	Inverted U-shape for some countries but not all of them
Franklin & Ruth (2012)	per cap CO_2 emissions	GDP per cap, Gini coefficient, ratio of exports to imports, inflation adjusted energy prices	US; 1800-2000	Time series, level, cubic; OLS, Prais-Winsten AR(1) regression model	Inverted U-shape
Zang & Zhao (2014)	per cap CO_2 emissions	GDP per cap, energy intensity, income inequality, urbanization, the share of industry sector in GDP	28 Chinese provinces; 1995-2010	Panel data, log-level, cubic; fixed effect model	N shaped curve
Yang, He & Chen (2015)	per cap CO_2 emissions, total SO_2, industrial(Ind) dust , Ind gas, Ind smoke, Ind SO_2, Ind waste water	real GDP, the percentage of exports & imports, domestic trade in GDP, the ratio of entry of FDI over GDP, population density	29 Chinese provinces; 1995-2010	Panel data; Level and log; fixed and random effects models, General Sensitivity Test	Positive linear. inverted-U and N shaped curves

CHAPTER 5

MODELS FOR THE EKC IN THE LITERATURE

In general, there are three types of data, which are cross-sectional, time series, and panel data (or longitudinal data), could be used for the econometric analysis (Gujarati, 2011, p.5). A panel data set involves repeated observations over the same units collected over a number of periods (Verbeek, 2004, p.341). In a way, panel data is a combined form of time series and cross sectional data. Panel data surpasses pure cross-sectional and time series estimation techniques in several ways. The advantages of panel data over pure time series data or cross-sectional data are thoroughly listed by Baltagi (2005). The most important ones of those advantages are mentioned here. First of all, panel data analysis control individual heterogeneity because it deals with entities or groups. Moreover, Baltagi (2005) declared that; "panel data give more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency". Finally, cross-sectional data analysis is not able to demonstrate the dynamics of adjustment while panel data analysis is way better able to study it. Therefore, panel data analysis is preferred for the estimation of our models due to its superiority over time series and cross sectional data.

In panel data, two dimensions, namely cross sectional and time, exist. For example, in our models, the dimension standing for cross section unit is country, while the other one presents time. In addition, panel data models have only one indices demonstrating cross sectional unit and time together even though they are mentioned as such two different dimensions above. Baltagi (2005) specified that the term $i = 1, 2,..N$, in the equation represents entities, households, individuals, countries, companies etc., while the term $t = 1, 2,.. T$ denotes time.

In this chapter, models used in the EKC literature and in our analyses are detailed. To do so, after giving general information about panel data in section 1, reduced form models of the EKC will be rendered in section 2. Then, models for our data set will be explained in the last part of the chapter.

5.1. PANEL DATA SPECIFICATION

After mentioning the advantages of the panel data, estimation techniques for panel data sets are clarified in this section. Other than pooled Ordinary Least Square (OLS), there are two types of models, which are fixed effects and random effects, specific to panel data. The main difference these two models is that unobserved individual or time effect is a part of an intercept term in a fixed effects, whilst it is a part of an error term in a random effect. Now, fixed effects and random effects models will be detailed respectively. After that, the Hausman Test used to decide about models for the analysis will be explained.

5.1.1. FIXED EFFECTS MODEL

The "fixed effect" term depends on the time-invariant nature of each entity's intercept which does not vary over time. However, intercept can change or differ regarding stations in our model. If intercept is written as β_{1it} instead of β_{1i} at the equation below, intercept of each entity will be time-variant **(**Gujarati, 2009, p.596).

$$Y_{it} = \beta_{1i} + \beta_2 X_{it} + \beta_3 Z_{it} + u_{it}$$

Fixed effect model is tested by F-test. The null hypothesis for the test is that OLS is favored over the fixed effect. The alternative hypothesis is that OLS is not favored over the fixed effect. Thus, if we reject the null hypothesis, we can use the fixed effect estimation. Otherwise, it is better proceed with OLS (Park, 2011, p.33).

5.1.2. RANDOM EFFECTS MODEL

Other name of this model is error components model (ECM) since its composite error term includes two components, which are the combined time series and cross-section error component, and individual specific, or cross-section error component. In other words, while a parameter estimate of a dummy variable, which is symbolized as ε_i at the equations below, is a part of the intercept in a fixed effect model, it is accepted as a part of the error component in a random effect model (Park, 2011, p.8). The difference among individuals or time periods can be seen in β_{1i} intercept in the fixed effect model is accepted as;

$$\beta_{1i} = \beta_{1i} + \varepsilon_i,$$

where ε_i is a fixed effect to individual or time period

Then the error term is combined with the traditional error term, u_{it} to form a composite error term, w_{it}:

$$w_{it} = \varepsilon_i + u_{it},$$

where ε_i is a random effect to individual or time period)

Hence, the equation for the Random Effect Model is;

$$Y_{it} = \beta_1 + \beta_2 X_{it} + \beta_3 Z_{it} + w_{it}$$

Random effect model is tested by Breusch – Pagan Lagrange Multiplier (LM) test. The null hypothesis for the test is that OLS is favored over the random effects. The alternative hypothesis is that OLS is not favored over the random effects. Thus, if we reject the null hypothesis, we can use the random effect model. Otherwise, it is better to apply OLS (Park, 2011, p.39).

5.1.3. HAUSMAN TEST

A random effect model and its fixed effect counterpart can be compared with the help of the Hausman Test. The test analyzes that whether the random effect model is efficient, which is the null hypothesis. To do so, the correlation between the individual effects and any other explanatory variables is examined. If individual effects are not correlated with any other independent variables, we fail to reject the null hypothesis; hence, the random effect model is appropriate. However, if the correlation between individual effects and any other regressor is detected, we reject the null hypothesis and the fixed effect model is efficient. The reason is that individual effects are parts of intercept in the fixed effect model and the correlation between explanatory variables and intercept does not violate any Gauss-Markov assumption so that the fixed effect model is Best Linear Unbiased Estimate (BLUE hereafter). On the other hand, in a random effect model, individual effects are parts of the error term. If they are correlated with any explanatory variables, the random effect model violates a Gauss-Markov assumption then it is not BLUE anymore (Park, 2011, p.41). Therefore, the random effect model is not efficient.

Briefly, the null hypothesis and the alternative hypothesis for the Hausman Test are as follows;

H_0: The Random Effect Model is appropriate

H_a: The Fixed Effect Model is appropriate

If we reject the null hypothesis, the fixed effects model is more appropriate. Otherwise, it is better to proceed with the random effects model.

5.2. MODEL SPECIFICATIONS FOR THE EKC HYPOTHESIS

Although there are plenty amount of empirical studies in the EKC literature, most of them usually use polynomial regression, which is the special type of linear regression. This is called as reduced form function or parametric model as well. Reduced form function may have both drawbacks and benefits. For instance, the reduced form EKC function is quite easy to apply compared to non – linear functional forms or non-parametric and semi-parametric models. However, it is a sort of black box because it does hide more than it demonstrates (Panayotou, 1997, p. 469). One of the problems is about the turning point. Caviglia-Harris et al. (2009) stated that parametric models imply that all countries within the panel have very same turning point. This cannot be true in real life. On the other hand, other than parametric methods, the use of spline or semiparametric methods would not help to get rid of the problems as well. As a result, using reduced form functions in the analyses can be chosen in spite of its drawbacks.

In order to observe the bell shaped curve, we need to take the square and/or the cubic term of the explanatory variable, which is per capita income for the EKC, in the reduced form function. There are two basic types of model specifications for the EKC that are quadratic and cubic models depending on only squared term or both squared and cubed terms are included to the function. Frankly, the cubic term is added to inspect whether there are inverse trend after the reduction of environmental degradation as income increases more. Furthermore, these equations can be transformed such as taking logarithms of the variables. Yang, He & Chen (2015) rendered four possible EKC reduced form functions which are level-level, log-log, level-log, and log-level. Although all functional forms can be observed in the EKC literature, we prefer to implement log-log form because this form not only smoothes the outliers in data set but also it directly gives the elasticity through its coefficients.

5.2.1. QUADRATIC SPECIFICATIONS

According to Holtz-Eakin and Selden (1995), Cole et al. (1997), Aslanidis (2009), and Caviglia-Harris et al. (2009) the quadratic equation for the EKC is;

$$Y_{it} = \alpha_{it} + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 Z_{it} + u_{it}$$

Y : environmental indicators

X : income

u_{it} : traditional error term

i : individuals and groups

t : time

α_{it}, β_1, β_2, and β_3 : coefficients

It is clear that, the square of the income term is taken to comply with the necessities of the polynomial function. That is why this equation is called quadratic form. The signs of the coefficients of X and X^2 determine the shape of the curve that helps to verify the existence of the EKC hypothesis. That is;

- $\beta_1 > 0$, $\beta_2 = 0$ then there is a monotonically increasing relationship between X and Y.
- $\beta_1 < 0$, $\beta_2 = 0$ then there is a monotonically decreasing relationship between X and Y.
- $\beta_1 > 0$ and $\beta_2 < 0$, then there is an inverted U-shape relationship between X and Y. In other words, the EKC hypothesis is valid.
- $\beta_1 < 0$ and $\beta_2 > 0$, then there is a U-shape relationship between X and Y. In other words, the EKC hypothesis is not valid.

Furthermore, if there is an inverted U-shape curve, there exists a turning point of income in which the environmental degradation is at its highest level. Most of the studies in the literature proving the validity of the EKC calculated the turning point as well. The calculation formula of turning point is as follows (Jobert, Karanfil & Tykhonenko, 2014, p. 1453).

$$Y = -\frac{\beta_1}{2\beta_2}$$

In this equation β_1 is the coefficient of per capita income and β_2 is the coefficient of the square of per capita income that are defined above, too.

5.2.2. CUBIC SPECIFICATIONS

According to Grossman & Krueger (1995), Panayotou (1997), De Bruyn (1997), Dinda (2004), Galeotti & Lanza (2005), and Akbostancı et al. (2009), the equation for cubic model to test the EKC hypothesis is revealed below.

$$Y_{it} = \alpha_{it} + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 X_{it}^3 + \beta_4 Z_{it} + u_{it}$$

Y : environmental indicators

X : income

u_{it}: traditional error term

i : individual and groups

t : time

α_{it}, β_1, β_2, β_3, and β_4 : coefficients

The situation is quite similar to the previous part. But in cubic model, in addition to the square of the income term, the cube of the income term is added to capture the rebound emissions at high income level if it exists as Franklin & Ruth (2012) emphasized. That is why it is called cubic model. The signs of the coefficients of X, X^2, and X^3 determine the shape of the curve as similar to its quadratic counterpart. Therefore, the existence of the EKC hypothesis can be verified or not. That is;

- $\beta_1 > 0$, $\beta_2 = \beta_3 = 0$ then there is a monotonically increasing relationship between X and Y.
- $\beta_1 < 0$, $\beta_2 = \beta_3 = 0$ then there is a monotonically decreasing relationship between X and Y.
- $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 = 0$ then there is an inverted U-shape relationship between X and Y. In other words, the EKC hypothesis is valid.
- $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 = 0$ then there is an U-shape relationship between X and Y.
- $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 > 0$ then there is a N-shape relationship between X and Y.

- $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 < 0$ then there is an inverted N-shape relationship between X and Y.

All these shape of the curves have different meanings. Monotonically decreasing curve means that environmental quality gets better as income increases, while monotonically increasing implies that environmental quality gets worse as income increases. Besides, inverted U-shape posited by the EKC reveals that environmental quality deteriorates with rise in income level up to the turning point. After that, environmental quality improves with an increase in income. Whereas, the inverted U-shape is literally inverted form of U-shape because it suggests the improvements in environmental quality as income rises, but after some point it starts to worsen with income increases (Fan & Zheng, 2013, p.111).

In addition to these, N-shaped curve signifies that environmental degradation starts rising again after a reduction to a specific level (Kijima, Nishide, & Ohyama, 2010, p.1190). As Choi, Heshmati & Cho (2010) specified that improvements in environmental quality with the help of environment-friendly development path cannot continue, it would be worsen again. Inverted N-shaped graph means the opposite of N-shaped one; that is, environmental deterioration starts falling again after an increase to a certain level. Aforementioned curve shapes can be graphically seen at Figure 5-1 in the following page.

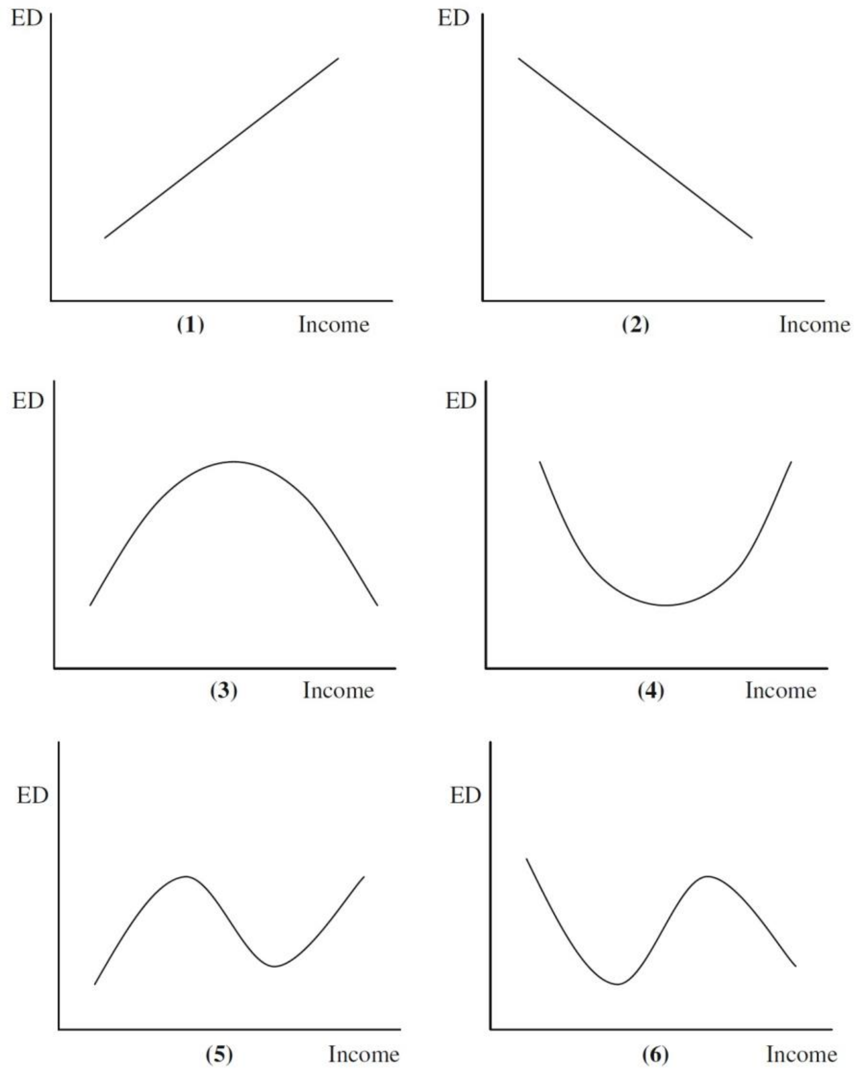

Figure 5-1: Graphical representations of income – environmental degradation (ED) (Mythili & Mukherjee, 2011, p.635)

CHAPTER 6

DATA AND MODELS

In this chapter, information about dependent and independent variables will be given in section 6.1 and 6.2 then descriptive statistics about these variables will be exhibited in section 6.3. Our assumption in our models is accepting people in countries are homogenous (Xu, 2003, p.69). Besides, Franklin & Ruth (2012) adverted that per capita values help us to focus on changes in qualitative aspects as well. Hence, it is much more suitable to use per capita term for variables at both hand sides of the equation

6.1. DEPENDENT VARIABLE

Metric tons per capita CO_2 emission is used as a dependent variable in order to measure the environmental degradation which is emphasized in the EKC theory. Carbon emission data are derived from Emission Database for Global Atmospheric Research (hereafter EDGAR). Metric tons per capita CO_2 emission data consist of burning of fossil fuel and industrial process emissions which are cement production, non-energy use of fuels, carbonate use of limestone and dolomite and other combustion. Emissions from large cycle biomass burning such as forest fires and short cycle biomass burning like agricultural waste burning are not included in metric tons per capita CO_2 emission data here. In Figure 6-1, Figure 6-2, and Figure 6-3 the most emitting countries in 88 countries, which is Qatar, in emerging countries, which is Poland, and in high income OECD countries, which is Luxembourg, are shown respectively.

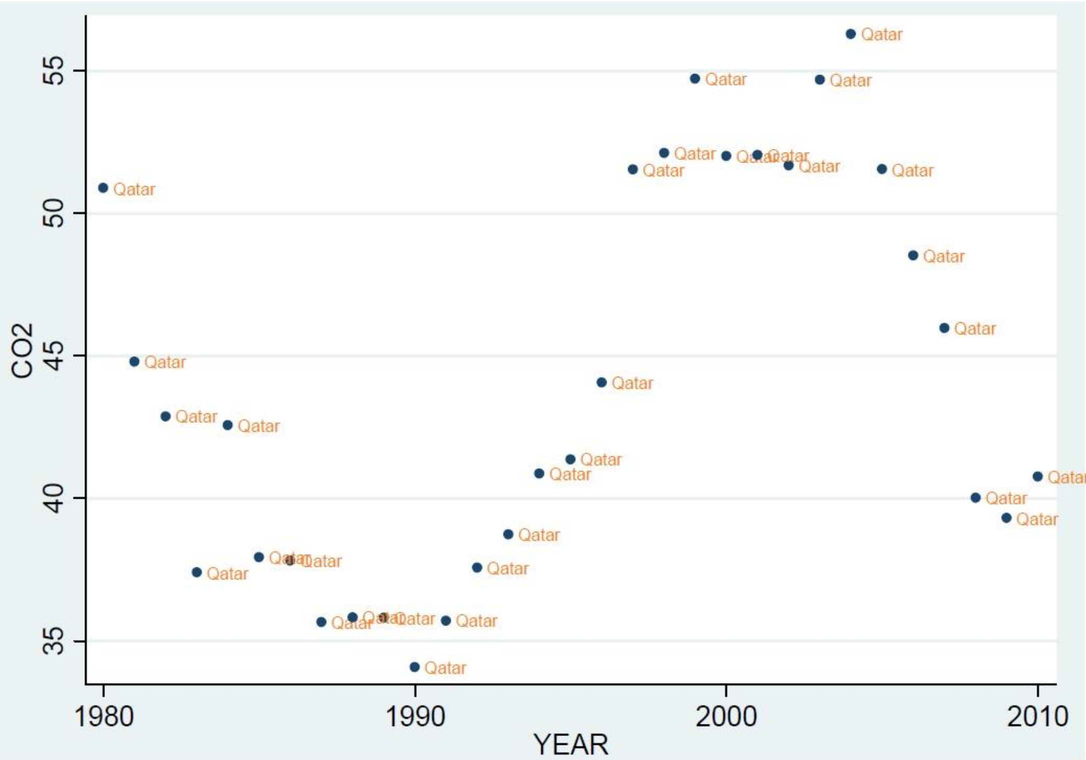

Figure 6-1: per capita CO_2 emissions of Qatar

According to World Development Indicators (2014), the countries having the highest per capita emissions are not even among the countries having the highest total emissions. For instance, the top 5 per capita emitters were Qatar, Trinidad and Tobago, Kuwait, Brunei Darussalam, and Aruba, while the top 5 total emitters are Chine, US, India, Russian Federation, and Japan in 2010. This situation clearly makes the distinction between per capita and total emissions.

To prevent some problems such as misspecification of conditional mean, bias of estimates, and inconsistency, the dependent variable is transformed by taking the natural logarithm of it (Cameron & Trivedi, 2009, p.71). Additionally, taking the natural logarithm of the data mostly eliminates the skewness and kurtosis (Cameron & Trivedi, 2009, p.74). In other words, outlier problem is overcome with taking the logarithms of the variables. Thus, the dependent variable of the model is the natural logarithm of metric tons per capita CO_2 emission.

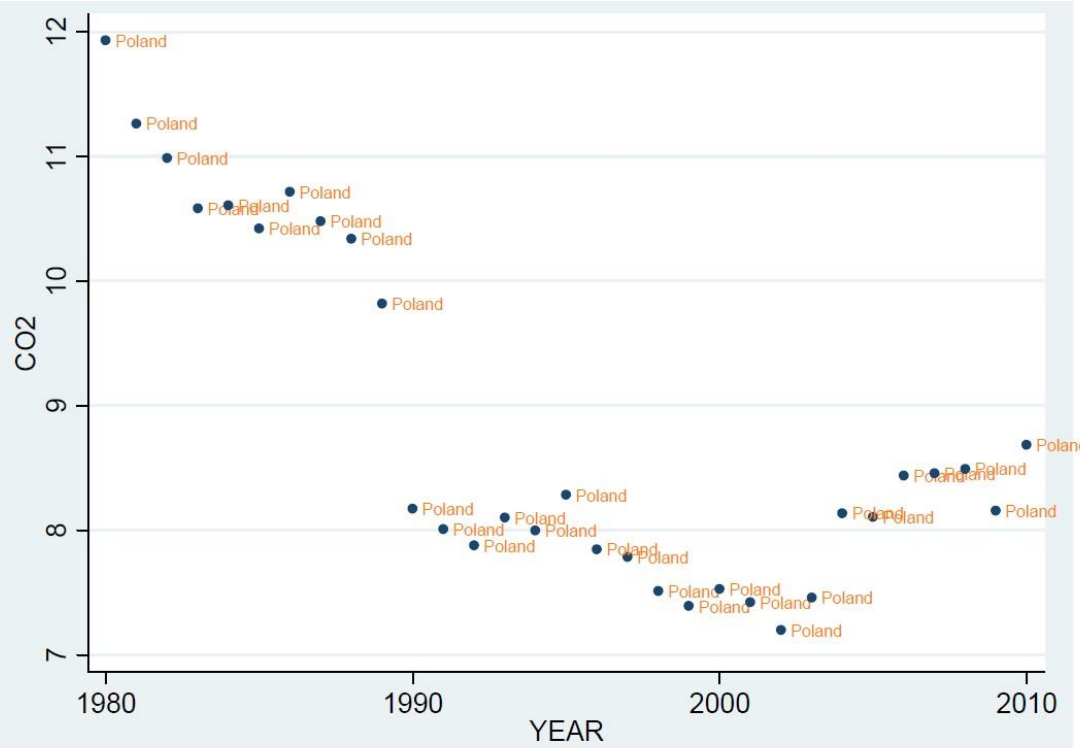

Figure 6-2: per capita CO_2 emissions of Poland

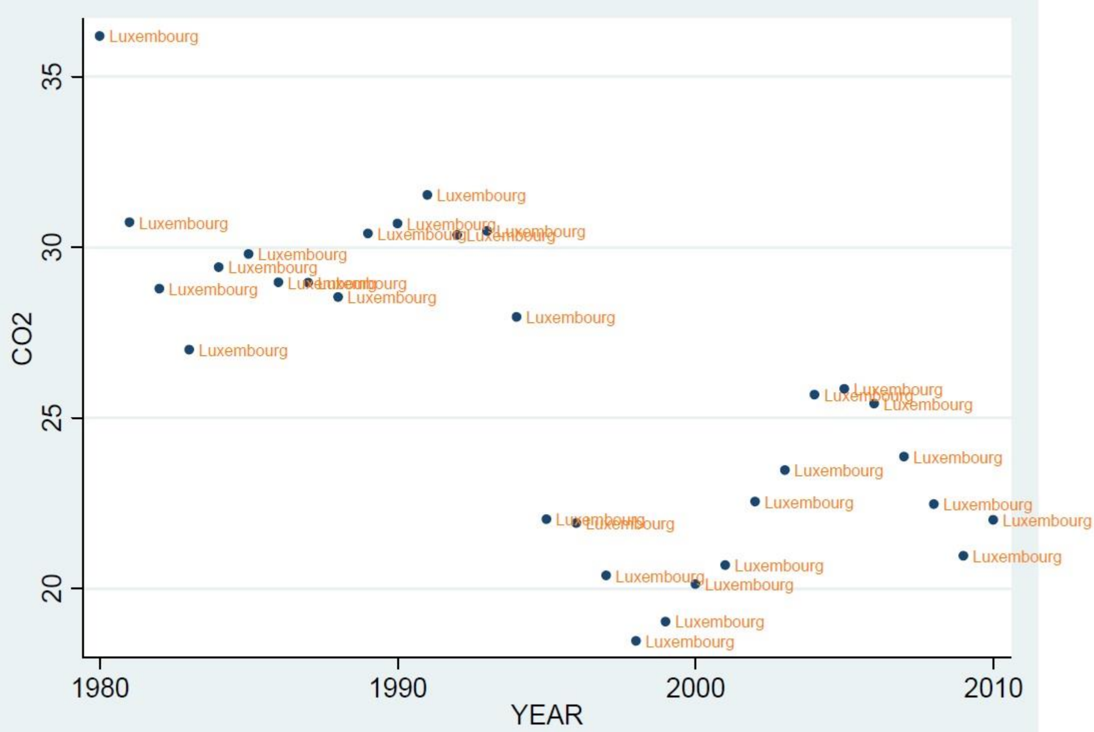

Figure 6-3: per capita CO_2 emissions of Luxembourg

6.2. INDEPENDENT (EXPLANATORY) VARIABLES

As it was mentioned before, the independent variable of the EKC hypothesis is GDP per capita. However, there are many empirical studies using different independent variables, which are listed in the literature part, in addition to the GDP per capita. In this model, we stick to the core of the hypothesis and use the per capita GDP as an independent variable. Then, per capita energy use is integrated into the model to compare the results of both models and to observe the change if there exists any. Besides, natural logarithms of the independent variables are taken owing to the reasons stated above.

6.2.1. GDP PER CAPITA

GDP per capita data are obtained from The Conference Board Total Economy Database. Data are converted to 2013 price level through updated Purchasing Power Parity (hereafter PPP) value in 2005. As Ravallion, Heil & Jalan (2000) remarked that GDP with PPP term offers the income as comparable units with respect to countries' living standards. For that reason, GDP per capita in PPP term is preferred for analyses.

6.2.2. PER CAPITA ENERGY USE

Apart from income as an independent variable, per capita energy use is also chosen because we want to measure its impact on per capita carbon emissions. As Jobert et al. (2014) affirm that energy consumption is an environmentally significant input factor due to its severe environmental effects. Besides, Mcconnell (1997) claims that the relationship between income and CO_2 emissions is caused from the connection between income and energy consumption. Hence, including the per capita energy use in the analysis may help us to observe its impact on carbon emission. Per capita energy use data are derived from World Development Indicators, World Bank. Again, the natural logarithm of the variable is taken.

6.3. DESCRIPTIVE STATISTICS

Descriptive statistics of our first data set for 26 high income OECD countries, descriptive statistics of our second data set for 52 emerging countries and descriptive statistics of our third data set for 88 countries are exhibited in Table 6-1, Table 6-2, and Table 6-3., respectively.

Table 6-1: Descriptive statistics for variables of OECD countries, Model 1

Variable	**Obs.**	**Mean**	**Standard Deviation**	**Min**	**Max**
CO_2_pc	806	10.375	4.874	2.836	36.190
ln(CO_2_pc)	806	2.250	.410	1.042	3.589
GDP_pc	806	31710.84	11257.670	5929.385	89561.680
ln(GDP_pc)	806	10.302	.364	8.688	11.403
D(lnGDP_pc)	780	.019	.0262	-.1292	.100
$(\text{lnGDP\_pc})^2$	806	106.263	7.415	75.476	130.021
$D(\text{lnGDP\_pc})^2$	780	.384	.534	-2.464	1.931
$(\text{lnGDP\_pc})^3$	806	1097.421	113.761	655.709	1482.590
$D(\text{lnGDP\_pc})^3$	780	5.902	8.202	-35.239	31.006
ENUSE_pc	806	4450.060	2171.116	1006.494	16904.900
ln(ENUSE_pc)	806	8.294	.463	6.914	9.736

It can be clearly seen from the tables, the mean and minimum values of GDP per capita, CO_2 emissions per capita and energy use per capita in Model 3 are less than Model 1, because developing countries and undeveloped countries apparently use less energy and release less CO_2 emissions.

Moreover, the means of per capita CO_2 emissions, per capita energy use and GDP per capita for Model 3 are tripled the same indicators of Model 2. Whereas, these values of Model 1 are almost five times more than the values of Model 2. Even these comparisons are sufficient to distinguish between the developed countries and emerging ones.

Table 6-2: Descriptive statistics for variables of emerging countries, Model 2

Variable	Obs.	Mean	Standard Deviation	Min	Max
CO_2_pc	1602	2.086	2.180	.024	11.930
ln(CO_2_pc)	1602	.110	1.273	-3.715	2.479
GDP_pc	1602	5050.004	3834.672	167.465	24427.170
ln(GDP_pc)	1602	8.134	1.012	5.121	10.103
D(lnGDP_pc)	1560	.015	.054	-.954	.405
$(\ln GDP\_pc)^2$	1602	67.187	15.739	26.222	102.080
$D(\ln GDP\_pc)^2$	1560	.249	.897	-16.554	6.869
$(\ln GDP\_pc)^3$	1602	562.380	187.183	134.279	1031.358
$D(\ln GDP\_pc)^3$	1560	3.095	11.505	-215.579	87.358
ENUSE_pc	1602	888.535	695.504	101.147	3559.326
ln(ENUSE_pc)	1602	6.541	.691	4.617	8.177
D(lnENUSE_pc)	1560	.011	.057	-.351	.361

Table 6-3: Descriptive statistics for variables of all countries, Model 3

Variable	Obs.	Mean	Standard Deviation	Min	Max
CO_2_pc	2728	6.111	7.411	0.024	56.283
ln(CO_2_pc)	2728	1.010	1.500	-3.714	4.030
GDP_pc	2728	16495.940	18588.010	167.465	258425.700
ln(GDP_pc)	2728	9.018	1.348	5.121	12.462
D(lnGDP_pc)	2640	0.016	0.048	-0.954	0.405
$(\ln GDP\_pc)^2$	2728	83.134	23.455	26.222	155.311
$D(\ln GDP\_pc)^2$	2640	0.288	0.869	-16.554	6.869
$(\ln GDP\_pc)^3$	2728	781.147	314.235	134.279	1935.536
$D(\ln GDP\_pc)^3$	2640	3.946	12.317	-215.579	87.358
ENUSE_pc	2728	2528.731	2970.380	101.147	23109.770
ln(ENUSE_pc)	2728	7.256	1.097	4.617	10.048
D(lnENUSE_pc)	2640	0.012	0.060	-0.364	0.494

6.4. MODELS FOR ANALYSES

The main objective of this study is to detect the relationship between carbon emissions and income level as well as putting an emphasis on the influence of energy use on this relationship. So as to reach meaningful results, panel data will be used in the analyses. As it was stated before, panel data offer less collinearity, heterogeneity among variables, more degrees of freedom and more efficiency.

Although variables are chosen regarding the theoretical and empirical literature, data availability is a crucial factor for determining not only dependent variable but also independent variables for this study. The motivation of this study is testing the EKC hypothesis because there are conflicting arguments in the literature about the theory.

There are three fundamental models with respect to income distinctions are analyzed in this thesis. The first model is formed for 26 high income OECD countries (OECD, 2011) according to availability of the data between 1980 and 2010. OECD country classification as of 2010 is used for this purpose. Per capita CO_2 emission and GDP per capita are base variables. As it is understood, the focus of this model is searching for the EKC for developed countries. Then, Model 1 is reformed by adding another explanatory variable, energy use per capita; but, other variables, time horizon, and countries are held constant. The second model is set for 52 emerging countries under the same parameters as Model 1 in order to compare the results of developed and developing countries' relationship between per capita income and per capita CO_2 emissions. Again, the second model is extended by adding per capita energy use as explanatory variable. The last model is mixed version of Model 1 and Model 2; however, it includes more countries than their summation because there exist some states accepted as neither developed nor emerging countries such as Trinidad & Tobago and United Arab Emirates. Consequently, the third model is established for 88 countries regarding the availability of data. The same variables and time horizon are used for 88 countries. Additionally, the models are meant to be balanced since each country is observed 31 times. Lists of 26 high income OECD countries, 52 emerging countries, and all 88 countries used in analyses are exhibited in Appendix B.

Furthermore, all variables are taken as their natural logarithms forms regarding to the literature. There are level-level, log-log, level-log, and log-level forms of equations exist in the literature; however, log-log form is the common form for application.

The one of the most crucial reasons for using log-log form is eliminating outliers as it was stated before. Mathematically, taking the natural logarithm of series helps to smooth the data. In addition, coefficients of the variables give the elasticity if log-log form is utilized. As a result, log-log form is chosen due to these outweighing advantages.

Quadratic and cubic specifications for models are as follows for Model 1, Model 2, and Model 3:

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2(lnGDP\_pc)_{it} + \beta_3(lnGDP\_pc)_{it}^2 + u_{it}$$

$$\begin{aligned}\ln\left(CO_2\_pc\right)_{it} = {} & \beta_{1i} + \beta_2(lnGDP\_pc)_{it} + \beta_3(lnGDP\_pc)_{it}^2 \\ & + \beta_4(lnGDP\_pc)_{it}^3 + u_{it}\end{aligned}$$

$$\begin{aligned}\ln\left(CO_2\_pc\right)_{it} = {} & \beta_{1i} + \beta_2(lnGDP\_pc)_{it} + \beta_3(lnGDP\_pc)_{it}^2 \\ & + \beta_4(lnENUSE\_pc)_{it}\ u_{it}\end{aligned}$$

$$\begin{aligned}\ln\left(CO_2\_pc\right)_{it} = {} & \beta_{1i} + \beta_2(lnGDP\_pc)_{it} + \beta_3(lnGDP\_pc)_{it}^2 \\ & + \beta_4(lnGDP\_pc)_{it}^3 + \beta_5(lnENUSE\_pc)_{it}\ u_{it}\end{aligned}$$

ln(CO_2_pc) : natural logarithm of per capita CO_2 emissions

ln(GDP_pc) : natural logarithm of GDP per capita

ln(ENUSE_pc) : natural logarithm of energy use per capita

u_{it} : traditional error term

i = 1,2,..,26 for Model 1; 1,2,..,52 for Model 2; and 1,2,..,88 for Model 3 (countries)

t = 1,2,3,...31 (years)

CHAPTER 7

EMPIRICAL ANALYSES AND RESULTS

In previous parts, which elements may affect the CO_2 emission level of countries are described. Although many factors may have an impact on CO_2 emissions, two main contributors, income and energy use, are examined in this study. In other words, per capita GDP and per capita energy use are expected to affect the per capita CO_2 emissions; hence, empirical analysis of this impact will be exhibited in this chapter.

Before starting analyses, unit root test, namely Pesaran CADF, is applied to all variables in order to have stationary data. Detailed explanation about unit root test and results of the test can be found in Appendix C because this topic is not the focus point of our analyses, but brief conditions are as follows:

Results reveal that, natural logarithm of per capita CO_2 emissions is stationary for all the cases, whilst natural logarithm of per capita GDP, its square and cubic forms are all stationary at the first difference. Thereby, all analyses are proceeding with the first difference of these variables. The first difference of the GDP per capita is also called GDP per capita growth rate. Besides, natural logarithm of per capita energy use is stationary at level for the first model, whereas it is stationary at the first difference for the second and third models. Hence, the first difference is taken to proceed analyses for the second and third models.

In the first section of the chapter, the analyses about the 26 high income OECD countries are carried out. To begin with, natural logarithm of per capita CO_2 emissions is regressed on natural logarithm of GDP per capita. This one is named as Model 1.1. Then, per capita energy use is added to the analysis as an explanatory variable in addition to the per capita GDP which is labeled as Model 1.2 in the second section.

The third and fourth sections are devoted for the analyses of 52 emerging countries. The same analyses for the developed ones are applied to 52 countries in this part, which are called as Model 2.1 and Model 2.2, respectively.

Aforementioned analyses for 88 countries can be found in the fifth and the sixth section of this part, which are called as Model 3.1 and Model 3.2, respectively. As stated before, lists of all these countries used in the analysis can be found in Appendix B and descriptive statistics of the variables for both models can be seen at Table 6-1, Table 6-2, and Table 6-3.

It is good to specify that our sample choices are slightly affected from technical reasons as well as data availability. Jobert et al. (2014) render that inverted U-shape can be observed only after 1980s depending on their previous study about instability of the EKC using different countries and different time horizons. Therefore, focusing more on the time periods after 1980s for the EKC makes more sense based on literature.

Furthermore, structural break is not taken into consideration while doing analyses. Thereby, interpretation of the results should be done very cautiously.

7.1. ESTIMATION RESULTS FOR MODEL 1.1

Our first model for high-income OECD countries is set up both the form of quadratic and cubic functions that is mentioned before. Models are:

$$\ln(CO_2\_pc)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + u_{it}$$

$$\ln(CO_2\_pc)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + \beta_4 D(lnGDP\_pc)^3_{it} + u_{it}$$

are estimated by using Pooled OLS, Fixed Effects, and Random Effects which are exhibited in Appendix D.

The crucial thing for the analysis is deciding about the estimation method. At this point, some test help to select the best estimation techniques for the model. To begin with, F-Test reveals the significance of the individual effects and compares the Pooled OLS and the fixed effects model (Baltagi, 2008, p.29). Moreover, the Breusch-Pagan Lagrange Multiplier (LM) Test is utilized to decide between simple OLS regression and random effects model (Torres-Reyna, 2007, p.32). Finally, the Hausman Test is used to determine appropriateness of random effects versus fixed effects that is elaborated in previous chapter.

Regarding Stata results of both quadratic and cubic forms, 25 country dummies are observed because 26 countries are involved in the analysis. Park (2011) states that one of the countries' intercept is taken as a reference point to avoid multicollinearity. It is the reason for creating 25 country dummies for Model 1. The null hypothesis for F-test is that all of the country specific dummy coefficients are zero excluding the benchmark point.

The F-Test gives the following results for the quadratic form of Model 1.1:

$$F\,(25, 752) = 209.87 \qquad \text{Prob} > F = 0.000$$

The F-Test gives the following results for the cubic form of Model 1.1:

$$F\,(25, 751) = 250.96 \qquad \text{Prob} > F = 0.000$$

According to test results, we obviously reject the null hypothesis meaning that country specific dummy parameters are not equal to zero. Hence, the fixed effects model is appropriate for both quadratic and cubic equation rather than pooled OLS.

After deciding the efficiency of fixed effects over the pooled OLS, it is time to choose between random effects and the pooled OLS. Breusch-Pagan LM Test can be used for this purpose. As Park (2011**)** asserts that the null hypothesis for the test is that time-specific or individual-specific error variance components are zero. Symbolically, H_0: σ^2_u=0. This statement means that if the null hypothesis is rejected, the random effects model is preferred; otherwise, the pooled OLS is more appropriate (Bölük & Mert, 2014, p.443). Table 7-1 clearly demonstrates that test results are statistically significant at %0.1 level for both quadratic and cubic forms. This situation carries with the rejection of the null hypothesis. As a result, the random effects model is favored over the pooled OLS.

Depending on the results of F-test and Breusch-Pagan LM test, the pooled OLS is eliminated. Next step is deciding which method is efficient, the fixed effects model or the random effects model.

Table 7-1: Breusch-Pagan LM Test Results 1.1

quadratic

lnCO$_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
lnCO$_2$_pc	.165	.406
e	.018	.134
u	.080	.283
Test: Var(u) = 0		
	chibar2(01) = 7745.780	
	Prob > chibar2 = 0.000	

cubic

lnCO$_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
lnCO$_2$_pc	.165	.406
e	.015	.124
u	.082	.286
Test: Var(u) = 0		
	chibar2(01) = 7529.070	
	Prob > chibar2 = 0.000	

Aforementioned, the Hausman test can be executed to decide whether the random effects or the fixed effects should be preferred. The null hypothesis for the test is that individual effect is not correlated with any regressors in the model (Paudel, Zapata & Susanto, 2005, p.334). Symbolically as H_0: (uit/ Xit) = 0. The results of the Hausman test are revealed at Table 7-2.

Table 7-2: Hausman test results for quadratic and cubic equations for Model 1.1

Quadratic

Test: H_0: difference in coefficients not systematic		
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)	
= -1.50	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Cubic

Test: H_0: difference in coefficients not systematic		
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)	
= -1.44	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

When the Hausman test is run in Stata, it gives the results, Table 7-2 shows. However, Stata warns: "…the model fitted on these data fails to meet the asymptotic assumptions of the Hausman test". According to Cameron & Trivedi (2009), this statement simply means that there is a problem about estimating standard errors of (V_b - V_B). The reason for this problem is that different estimates of the error variance are utilized in forming (Vb) and (VB), referring to variance estimate for fixed effects and random effects, respectively. When we face similar problem in our analysis, as Cameron & Trivedi (2009) suggest that it is better use the sigmamore option for executing Hausman test in Stata because this option denotes that both covariance matrices are based on the same estimated variance from the efficient estimator. The Hausman test results with sigmamore option are exhibited at Table 7-3. These results lead us to reject the null hypothesis for both quadratic and cubic form of the Model 1. In other words, fixed effects model is more appropriate instead of random effects.

Although Hausman test with sigmamore command in Stata helps to select the more appropriate model, there exists a test of overidentifying restrictions or orthogonality conditions. Schaffer & Stillman produced this so called overid test (n.d.) for Stata. The results of the test are at Table 7-4.

Table 7-3: Hausman test with sigmamore command for Model 1.1

Quadratic

Test: H_0: difference in coefficients not systematic	
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	17.99
Prob > chi2 =	0.0001

Cubic

Test: H_0: difference in coefficients not systematic	
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	16.25
Prob > chi2 =	0.0003

The null hypothesis for the test is that the regressors are not correlated with the error term (Lin & Liscow, 2013, p.12). That is, the random effects model is appropriate for the model is the null hypothesis itself. According to results, we reject the null hypothesis not only for the quadratic but also for cubic equation forms. Therefore, the fixed effects model is the best fit the data of Model 1.1, analogically to the Hausman test results.

Table 7-4: Results of Overidentification Tests for Model 1.1

Quadratic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	18.373	Chi-sq(2)	p-value =	0.0001

Cubic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	20.878	Chi-sq(3)	p-value =	0.0001

7.1.1. INTERPRETATION OF FIXED EFFECTS MODEL RESULTS FOR MODEL 1.1

One of the most difficult parts of the analysis is the model selection because this choice dramatically affects the deduction from the analysis. After several tests have been run, it has been already decided to use fixed effects for Model 1.1, covering both quadratic and cubic forms. The fixed effects estimation results and Driscoll-

Kraay Standard Errors estimations for Model 1.1 are together demonstrated below Table 7.5, while detailed results for these analyses can be found in Appendix E.

According to results, F statistics of both regression models, which are high enough, imply that we reject the null hypothesis. The null hypothesis for statistics is that the coefficients of all exogenous variables are zero (Baum, C. F., 2006, p.77). This means that our models are significant. When R^2 values are checked, the goodness of model can be observed. R^2 value of quadratic form is 0.895, whereas it is 0.910 for cubic form. These R^2 values purport that quadratic form model can approximately explain 90% of the reason for CO_2 emissions per capita, whilst cubic form one can almost explain 91% of the reason for the carbon emissions capita.

Table 7-5: Fixed Effects results for quadratic and cubic forms of Model 1.1

Sample	**Quadratic FE**	**Driscoll-Kraay Standard Errors**	**Cubic FE**	**Driscoll-Kraay Standard Errors**
Cons	2.255*** (.006)	2.255*** (.018)	2.252*** (.006)	2.252*** (.017)
D(lnGDP_pc)	-50.263*** (3.846)	-50.263*** (9.912)	-545.515*** (43.411)	-545.515*** (60.155)
$D(lnGDP\_pc)^2$	2.447*** (.187)	2.447*** (.482)	51.841*** (4.319)	51.841*** (6.117)
$D(lnGDP\_pc)^3$	-	-	-1.638*** (.1431)	-1.638*** (.207)
F-test	85.41	-	110.47	-
R-squared	0.895	0.185	0.910	0.306
Adj. R-sqr.	0.891	-	0.907	-
Observations	780	780	780	780
Countries	26	26	26	26

Note: Values in parentheses below coefficients are standard errors. ***, **, and * indicate significance at 1%, 5% and 10% levels.

Regarding fixed effects model results, all variables are statistically significant at 1% level in both quadratic and cubic forms. Besides, the significances of the variable remain same when Driscoll-Kraay Standard Errors are applied.

Moreover, signs of the coefficients imply U-shaped curve for the quadratic model, whilst they produce inverted N-shaped curve for the cubic model. Therefore, the EKC hypothesis is not valid for these analyses.

7.1.2. DIAGNOSTIC CHECKS

Now, it is time to check the problems of the model if there exists any. Heteroskedasticity is a common problem for cross-sectional data, while autocorrelation is an expected problem of time series data. It is very likely that both heteroskedasticity and autocorrelation are observed in panel data because this type of data are mixed of cross-sectional and time series data as mentioned before. Therefore, some tests are run to check the problem of cross sectional dependence, heteroskedasticity, and serial correlation.

7.1.2.1. CROSS SECTIONAL DEPENDENCE

Cross sectional dependence may cause a bias in test results; however, the model should be at least unbiased. Pesaran cross-sectional dependence (hereafter Pesaran CD) test is be used here in order to test whether residuals are correlated across countries or not. As Torres-Reyna (2007) stated that residuals are not correlated is the null hypothesis of the test. Pesaran CD test results are exhibited at Table 7-6 below:

Table 7-6: Pesaran CD Test for quadratic and cubic forms of Model 1.1

Quadratic

Pesaran's test of cross sectional independence = 6.489, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.521

Cubic

Pesaran's test of cross sectional independence = 7.529, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.518

It is clear that we reject the null hypothesis not only for quadratic form but also for cubic form. This means that cross-sectional dependence can be observed in both models.

7.1.2.2. HETEROSKEDASTICITY

Modified Wald test is used to determine heteroskedasticity in model. The null hypothesis for the test is homoskedasticity assumption, which is the constant variance. Rejection of the null hypothesis indicates the presence of heteroskedasticity. Test results are displayed at Table 7-7 in the following page.

Table 7-7: Modified Wald Test for Homoskedasticity Results for Model 1.1

Quadratic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (26) = 11607.04
Prob > chi2 = 0.000

Cubic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (26) = 5843.67
Prob > chi2 = 0.000

Based on test results, the null hypothesis is rejected for both quadratic and cubic form of equations. As it is stated above, it is a clear sign of presence of heteroscedasticity for both of the models.

7.1.2.3. SERIAL CORRELATION - AUTOCORRELATION

Torres-Reyna (2007) emphasizes that the serial correlation is a problem of macro panels with long time series (more than 20-30 years). Serial correlation results in the smaller standard errors of the coefficients. It also causes to higher R-squared. It can be said that the result may be misleading if there is serial correlation. A Wooldridge test is used to detect serial correlation in macro panel data. Results of the test can be seen Table 7-8.

The null hypothesis for the test is that there is no serial correlation. With respect to test results, we reject the null hypothesis under both conditions. Therefore, serial correlation problem exists for Model 1.

Table 7-8: Results of Wooldridge test for autocorrelation for Model 1.1

Quadratic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,26) =	74.482
Prob > F =	0.000

Cubic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,25) =	77.578
Prob > F =	0.000

7.1.2.4. DRISCOLL-KRAAY STANDARD ERRORS

Hoechle (2007) stated that it is better to use Driscoll-Kraay Standard Errors, if there the model is heteroskedastic, autocorrelated, and cross-sectionally dependent because it is evidently the way better than other types of standard errors in the presence of heteroskedasticity. Although this works well for the panel analysis with the long time period, it still surpasses other standard errors when the panel has quite short time horizon. Moreover, Azomahou & Phu (2006), Bölük & Mert (2014) and Garmann (2014) emphasize using the estimator which is developed by Driscoll and Kraay if the presence of heteroskedasticity, and spatial and serial dependence in the data are detected in fixed effects panel model. Therefore, we chose to apply Driscoll-Kraay Standard Errors for our fixed effects model. The results for these analyses are thoroughly exhibited in Appendix E, while the fixed effects results are given together with Driscoll-Kraay Standard Errors in all result tables.

7.2. MODEL 1 WITH PER CAPITA ENERGY USE VARIABLE (MODEL 1.2)

The same model in previous part is combined with other explanatory variable, per capita energy use. The models are as follows for this part:

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + \beta_4 (lnENUSE\_pc)_{it} + w_{it}$$

$$\ln(CO_2\_pc)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + \beta_4 D(lnGDP\_pc)^3_{it} + \beta_5(lnENUSE\_pc)_{it} + w_{it}$$

These models are also estimated by using Pooled OLS, Fixed Effects, and Random Effects that are displayed in Appendix D.

According to results of F-Test, Breusch Pagan LM Test, Hausman Test, and Sargan-Hansen Test, random effects model is found more preferable. After that, diagnostic checks such as Likehood Ratio test for heteroskedasticity, Wooldridge Test for autocorrelation, and both Pesaran's test of cross sectional independence and Friedman's test of cross sectional independence show that our data are cross-sectionally dependent, heteroskedastic, and autocorrelated. Hence, the Driscoll-Kraay Standard Errors will be applied to overcome these problems. All aforementioned test results related to these models can be found in Appendix E.

7.2.1. INTERPRETATION OF RANDOM EFFECTS MODEL RESULTS FOR MODEL 1.2

Random effects estimation and Robust Standard Errors estimations are both exhibited at Table 7-9. The results of the Wald chi2 statistics for both quadratic and cubic forms lead us to reject the null hypothesis. Hence, models are jointly significant. Besides, R^2 value of quadratic functional form is 0.730 and R^2 value of cubic functional form is 0.733. That is, nearly %73 of the CO_2 emissions can be explained by these models.

Due to the presence of heteroskedasticity and serial correlation, Robust Standard Errors is applied as it is stated above. All variables are statistically significant in RE models, whereas all variables except the per capita energy use and constant term are not significant in Robust Standard Errors models. In fact, the per capita energy use is significant at %1 level in both reduced forms models.

Table 7-9: Results of Random Effects and Robust RE for Model 1.2

Sample	Quadratic RE	Robust SE	Cubic RE	Robust SE
Cons	-3.979*** (.168)	-3.979*** (.482)	-3.890*** (.165)	-3.890*** (.558)
lnGDP_pc	-4.027* (2.544)	-4.027 (4.049)	-83.663*** (26.778)	-83.663** (56.915)
$D(lnGDP\_pc)^2$	.205* (.124)	.205 (.195)	8.177*** (2.668)	8.177** (5.536)
$D(lnGDP\_pc)^3$	-	-	-.265*** (.088)	-.265** (.179)
(lnENUSE_pc)	.750*** (.019)	.750*** (.062)	.740*** (.019)	.740*** (.070)
Wald chi2	2002.88	375.11	2164.34	786.06
R-squared	0.730	-	0.733	-
Observations	780	780	780	780
Countries	26	26	26	26

Note: Values in parentheses below coefficients are standard errors. ***, **, and * indicate significance at 1%, 5% and 10% levels.

Besides, signs of the coefficients give U-shaped curve for the quadratic model, while they resulted in inverted N-shaped curve for the cubic model according to results of Robust Standard Errors Models. Therefore, EKC hypothesis is not valid for these analyses as well.

For the per capita energy use, % 1 increase in energy use causes almost % 0.75 increase in per capita CO_2 emissions in both of the models. It can be concluded that there is a positive relationship between per capita energy use and per capita CO_2 emissions.

7.3. ESTIMATION RESULTS FOR MODEL 2 (MODEL 2.1)

The second model is exactly the opposite of the first model since it is developed for emerging countries. However, the data availability dictates the analysis so the model can be set up for 52 emerging countries. The very same time periods, between 1980 and 2010, and same dependent and independent variables which are per capita CO_2 emissions per capita income are used in the second model. Again, the quadratic and cubic functional forms of equations are formed for Model 2.1. These models are:

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)_{it}^2 + u_{it}$$

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)_{it}^2 + \beta_4 D(lnGDP\_pc)_{it}^3 + u_{it}$$

The estimation results of Pooled OLS, Fixed Effects, and Random Effects for these models are presented in Appendix D.

The essential thing for Model 2.1, just like for other models, is choosing the appropriate estimation techniques. Therefore, the F-Test, the Breusch-Pagan LM Test, and the Hausman Test are applied one by one so as to decide about the estimation method.

F-Test results rejecting the null hypothesis can be viewed below. It can be concluded with the help of F-Test results that fixed effects model is more suitable than pooled OLS for quadratic and cubic functional specifications together.

(quadratic)	$F\ (51, 1506) = 565.69$	$Prob > F = 0.000$
(cubic)	$F\ (51, 1505) = 562.90$	$Prob > F = 0.000$

The results of Breusch-Pagan LM Test, displayed at Table 7-10, imply that random effects model is more preferable than pooled OLS.

After these tests, we have to make a choice for our model between the fixed effects and the random effects. As this stage, the Hausman test helps us to decide which model is more appropriate. But, the standard Hausman test once again gives the negative results (see Appendix E). As a solution to this problem, one can execute not only the Hausman test with sigmamore command in Stata but also the Sargan-Hansen test.

Table 7-10: Breusch-Pagan LM Test Results for Model 2.1

quadratic

$lnCO_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2$_pc	1.622	1.274
e	.081	.284
u	1.252	1.119
Test: Var(u) = 0		
	chibar2(01) =	
	Prob > chibar2 = 0.000	

cubic

$lnCO_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2$_pc	1.622	1.274
e	.081	.284
u	1.202	1.096
Test: Var(u) = 0		
	chibar2(01) = 19305.04	
	Prob > chibar2 = 0.000	

Table 7-11: Hausman Test with sigmamore Results for Model 2.1

Quadratic

Test: H_0: difference in coefficients not systematic	
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	14.43
Prob > chi2 =	0.001

Cubic

Test: H_0: difference in coefficients not systematic	
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	17.88
Prob > chi2 =	0.001

Results of these tests, which are demonstrated in Table 7-11 and Table 7-12, recommend to use the fixed effects model rather that the random effects model. Therefore the fixed effects estimation is chosen for the model of 52 emerging countries to detect the EKC between per capita income and per capita CO_2 emissions for the time horizon between 1980 and 2010.

Table 7-12: overid Results for Model 2.1

Quadratic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	14.550	Chi-sq(2)	p-value =	0.001

Cubic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	18.052	Chi-sq(3)	p-value =	0.000

7.3.1. INTERPRETATION OF FIXED EFFECTS MODEL RESULTS FOR MODEL 2.1

Now, it is time to interpret the results of fixed effects estimations for quadratic and cubic functional forms. Table 7-13 shows the results of the fixed effects and Driscoll-Kraay Standard Errors estimations together. With respect to F statistics of the quadratic and cubic regressions, the overall effect of the models are good since the null hypotheses are rejected at both forms. Around 0.95 R^2 values are also high for both functional forms. However, it should be bear in mind that high R^2 values can be resulted from the presence of serial correlation. Therefore, it may not be a good indicator for all the time.

The estimation results indicate that all variables turned out to be individually significant when Dricoll-Kraay Standard Errors applied. For instance, the variable D(lnGDP_pc) which is per capita GDP grosth rate in cubic model became significant at 10% level after the application of Dricoll-Kraay Standard Errors. But, this situation is quite awkward because it is generally expected that the significance levels of variables decrease with robust standard errors. Yet, this assumption was reversed for this analysis. Besides, the significance levels of $D(lnGDP\_pc)^2$ and $D(lnGDP\_pc)^3$ increased to upper level as well in cubic specification.

Table 7-13: FE and Driscoll-Kraay SE results for Model 2.1

Sample	**Quadratic FE**	**Driscoll-Kraay Standard Errors**	**Cubic FE**	**Driscoll-Kraay Standard Errors**
Cons	-3.249*** (.008)	-3.249*** (.008)	.108*** (.008)	.108*** (.008)
D(lnGDP_pc)	-3.249*** (1.231)	-3.249** (1.391)	8.104 (6.7660)	8.104* (5.057)
$D(lnGDP\_pc)^2$	.2193*** (.074)	.219*** (.090)	-1.295* (.8901)	-1.295** (.624)
$D(lnGDP\_pc)^3$	-	-	.066** (.039)	.066*** (.026)
F-test	8.37	-	6.56	-
R-squared	0.952	0.011	0.952	0.223
Adj. R-sqr.	0.950	-	0.950	-
Observations	1560	1560	1560	1560
Countries	52	52	52	52

Note: Values in parentheses below coefficients are standard errors. ***, **, and * indicate significance at 1%, 5% and 10% levels.

Moreover, signs of the coefficients demonstrate U-shape relationship for quadratic functional form, while they imply N-shaped curve for cubic equation. As a result, the EKC does not exist for this set of emerging countries the year between 1980 and 2010.

7.3.2. DIAGNOSTIC CHECKS

As it is in previous part, we will start with checking the cross-sectional dependency. In order to detect the cross-sectional dependency, if it exists, Pesaran CD Test is applies. Apparently, the null hypotheses are rejected for quadratic and cubic form indicating the cross-sectional dependence. Test results can be seen at Table 7-14.

Table 7-14: Pesaran CD Test for Model 2.1

Quadratic

Pesaran's test of cross sectional independence = 33.059, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.568

Cubic

Pesaran's test of cross sectional independence =32.007, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.568

According to results of Wald test, at Table 7-15, we reject the null hypothesis for both models. These rejections refer to the presence of heteroskedasticity.

Table 7-15: Modified Wald Test for Homoskedasticity for Model 2.1

Quadratic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (52) = 43963.12
Prob > chi2 = 0.000

Cubic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (52) = 34660.13
Prob > chi2 = 0.000

To check the model for serial correlation, Wooldridge test of which results are displayed at Table 7-16 is carried out. The existence of serial correlation is confirmed with the rejection of the null hypotheses for quadratic and cubic functional forms.

Table 7-16: Wooldridge test for autocorrelation for Model 2.1

Quadratic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,51) =	110.144
Prob > F =	0.000

Cubic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,51) =	110.823
Prob > F =	0.000

The presence of cross-sectional dependence, heteroskedasticity, and serial correlation lead us to use the Driscoll-Kraay Standard Errors. The results of these standard errors estimations are given together with the fixed effects estimations of the quadratic and cubic functional forms of this extended model.

7.4. ESTIMATION RESULTS FOR MODEL 2 (MODEL 2.2)

In this model, the previous model is combined with other explanatory variable, per capita energy use. The analyses are yet again carried out with panel data estimation techniques for 52 emerging countries between 1980 and 2010. Model 2.2 for quadratic and cubic functional forms are as follows:

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + \beta_4 D(lnENUSE\_pc)_{it} + u_{it}$$

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + \beta_4 D(lnGDP\_pc)^3_{it} + \beta_5 D(lnENUSE\_pc)_{it} + u_{it}$$

Just like for other models, these models are estimated by using Pooled OLS, Fixed Effects, and Random Effects that are demonstrated in Appendix D.

Results of F-Test, Breusch Pagan LM Test, Hausman Test, and Sargan-Hansen Test help us to decide about our estimation technique. The fixed effects model is found more appropriate. Then, diagnostic checks confirm the presence of cross-sectional dependence, heteroskedasticity, and autocorrelation. Therefore, the Driscoll-Kraay Standard Errors is executed to get rid of these problems. All tests related to Model 2.2 can be found in Appendix E.

7.4.1. INTERPRETATION OF FIXED EFFECTS MODEL RESULTS FOR MODEL 2.2

As it is explained in previous part, it has been already decided to use fixed effects model depending on the tests' results.

Table 7-17 exhibits the results of the fixed effects and Driscoll-Kraay Standard Errors estimations together. F statistics of the quadratic and cubic regressions suggest the rejection of the null hypothesis. It can be deduced that our extended models with per capita energy use variable fit the data well at %1 significance level. In addition to this, almost 0.95 R^2 values are quite good for both functional forms that can explain the reason for %95 of per capita CO_2 emissions.

Table 7-17: Fixed Effects Model and Driscoll-Kraay Results for Model 2.2

Sample	**Quadratic FE**	**Driscoll-Kraay Standard Errors**	**Cubic FE**	**Driscoll-Kraay Standard Errors**
Cons	.105*** (.008)	.105*** (.042)	.106*** (.008)	.106*** (.042)
D(lnGDP_pc)	-3.080*** (1.230)	-3.080** (1.354)	8.765* (6.754)	8.765** (4.970)
$D(lnGDP\_pc)^2$	.201*** (.074)	.201*** (.087)	-1.379* (.889)	-1.379** (.608)
$D(lnGDP\_pc)^3$	-	-	.069** (.039)	.069*** (.025)
D(lnENUSE_pc)	.391*** (.138)	.391*** (.125)	.398*** (.138)	.398*** (.128)
F-test	8.29	-	7.02	-
R-squared	0.952	0.014	0.952	0.018
Adj. R-sqr.	0.950	-	0.950	-
Observations	1560	1560	1560	1560
Countries	52	52	52	52

Note: Values in parentheses below coefficients are standard errors. ***, **, and * indicate significance at 1%, 5% and 10% levels.

The estimation results point out that all variables have significant association with $lnCO_2\_pc$ although their significance levels differ. When the Driscoll-Kraay Standard Errors model is carried out, all variables are still significant at both functional forms. The significance levels of D(lnGDP_pc), $D(lnGDP\_pc)^2$, and $D(lnGDP\_pc)^3$ at cubic form passed to upper significance level, while the significance level of D(lnGDP_pc) declined from 1% to 5% when Driscoll-Kraay applied. Besides, per capita energy use is significant at 1 per cent level in both functional specifications as well as it has a positive sign which means positive relationship between energy use and carbon emissions. Frankly, %1 increase in per capita energy use causes nearly %0.40 rise in per capita CO_2 emission.

Furthermore, signs of the coefficients exhibit U-shape relationship for quadratic functional form and N-shape relationship can be observed for cubic functional form. It can be concluded that the EKC hypothesis is not valid under these circumstances.

7.5. ESTIMATION RESULTS FOR MODEL 3 (MODEL 3.1)

The third model is sort of combination of the first and the second models because it is developed for all countries all over the world without the income distinction. However, the availability of the data restricts the analysis for 88 countries. The time periods, between 1980 and 2010, dependent and independent variables are remain same for this model as well. The quadratic and cubic functional forms of equations are established for both Model 3.1 and Model 3.2 in order to detect the EKC is it exists. These models are:

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + u_{it}$$

$$\ln\left(CO_2\_pc\right)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)^2_{it} + \beta_4 D(lnGDP\_pc)^3_{it} + u_{it}$$

The results of Pooled OLS, Fixed Effects, and Random Effects for these models are together can be found in Appendix D.

The essential thing for Model 3.1, just like for other models, is choosing the appropriate estimation techniques. Therefore, the F-Test, the Breusch-Pagan LM Test, and the Hausman Test are applied one by one so as to decide about the estimation method.

F-Test results implying the rejection of the null hypothesis can be seen below. These results help to conclude that fixed effects is mode preferable than pooled OLS for quadratic and cubic forms together.

(quadratic) $F\ (87, 2550) = 1062.48$ $\text{Prob} > F = 0.000$

(cubic) $F\ (87, 2549) = 1062.84$ $\text{Prob} > F = 0.000$

Then, following the results of Breusch-Pagan LM Test, exhibited at Table 7-18, we reject the null and determine that random effects is favorable over pooled OLS.

Table 7-18: Breusch-Pagan LM Test Results for Model 3.1

Quadratic

$lnCO_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2$_pc	2.247	1.499
e	0.060	0.245
u	1.782	1.335
Test: Var(u) = 0		
	chibar2(01) = 34012.04	
	Prob > chibar2 = 0.000	

Cubic

$lnCO_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2$_pc	2.247	1.499
e	0.060	0.245
u	1.474	1.214
Test: Var(u) = 0		
	chibar2(01) = 33560.63	
	Prob > chibar2 = 0.000	

After ruling out the pooled OLS, we have to select the fixed effects or the random effects for our model. As mentioned earlier, the Hausman test helps us to take a decision. However, the standard Hausman test again gives the negative results (see Appendix E) that we have the similar problem before. In order to get rid of this problem, we run both the Hausman test with sigmamore command in Stata that is exhibited at Table 7-19.

Table 7-19: Hausman Test with sigmamore Results for Model 3.1

Quadratic

Test: H_0: difference in coefficients not systematic	
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	22.41
Prob > chi2 =	0.000

Cubic

Test: H_0: difference in coefficients not systematic	
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	45.26
Prob > chi2 =	0.000

Then the Sargan-Hansen test is run to be sure about the model selection. Test result is revealed in Table 7-20, below. Both of the tests suggest us to use the fixed effects model instead of the random effects model. Thus, the fixed effects estimation is chosen for the model of 88 countries all over the world.

Table 7-20: overid Results for Model 3.1

Quadratic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	22.586	Chi-sq(2)	p-value =	0.000

Cubic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	46.003	Chi-sq(2)	p-value =	0.000

7.5.1. INTERPRETATION OF FIXED EFFECTS MODEL RESULTS FOR MODEL 3.1

Following to results of previous tests it is decided to use fixed effects estimation for our extended model.

Table 7-21 reveals the results of the fixed effects and Driscoll-Kraay Standard Errors estimations. Both of the F statistics of the quadratic and cubic regressions signify the rejection of the null hypothesis. It can be deducted that there exist joint significance of the independent variables in both models. Besides, approximately 0.97 R^2 values are quite high for both functional forms.

The individual significance of the $D(lnGDP\_pc)^2$ increased from 5 per cent level to 1 per cent level when Driscoll-Kraay applied while the D(lnGDP_pc) or GDP per capita growth rate was still significant at 10 per cent level in quadratic equation. In cubic form, the individual significance of all variables diminished from 5 per cent level to 10 per cent level after the application of Driscoll-Kraay. Yet, all variables are significant at both functional forms.

Table 7-21: FE and Driscoll-Kraay SE results for Model 3.1

Sample	Quadratic FE	Driscoll-Kraay Standard Errors	Cubic FE	Driscoll-Kraay Standard Errors
Cons	1.004*** (.005)	1.004*** (.031)	1.003*** (.005)	1.003*** (.031)
D(lnGDP_pc)	-1.028* (0.691)	-1.028* (.661)	-6.409** (2.818)	-6.409* (3.908)
D(lnGDP_pc)^2	.082** (.038)	.082*** (.032)	.701** (.317)	.701* (.4531)
D(lnGDP_pc)^3	-	-	-.023** (.012)	-.023* (.017)
F-test	10.54	-	10.54	-
R-squared	0.974	0.008	0.974	0.010
Adj. R-sqr.	0.973	-	0.973	-
Observations	2640	2640	2640	2640
Countries	88	88	88	88

Note: Values in parentheses below coefficients are standard errors. ***, **, and * indicate significance at 1%, 5% and 10% levels.

Moreover, signs of the coefficients demonstrate U-shape relationship for quadratic model and inverted N-shaped curve for cubic one. As a result, the EKC does not exist for this set of 88 countries the year between 1980 and 2010.

7.5.2. DIAGNOSTIC CHECKS

In order to detect the cross-sectional dependency, if it exists, Pesaran CD Test is applies. Apparently, the null hypotheses are rejected for quadratic and cubic form indicating the cross-sectional dependence. Test results can be seen at Table 7-22.

Table 7-22: Pesaran CD Test for Model 3.1

Quadratic

Pesaran's test of cross sectional independence = 36.148, Pr = 0.0000
Average absolute value of the off-diagonal elements = 0.553

Cubic

Pesaran's test of cross sectional independence =36.518, Pr = 0.0000
Average absolute value of the off-diagonal elements = 0.555

According to results of Wald test, at Table 7-23, we reject the null hypothesis for both models. These rejections refer to the presence of heteroskedasticity.

Table 7-23: Modified Wald Test for Homoskedasticity for Model 3.1

Quadratic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (88) = 1.4e+05
Prob > chi2 = 0.000

Cubic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (88) = 1.4e+05
Prob > chi2 = 0.000

To check the model for serial correlation, Wooldridge test of which results are displayed at Table 7-24 is carried out. The existence of serial correlation is confirmed with the rejection of the null hypotheses for quadratic and cubic functional forms.

Table 7-24: Wooldridge test for autocorrelation for Model 3.1

Quadratic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,87) =	130.380
Prob > F =	0.000

Cubic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,87) =	130.380
Prob > F =	0.000

The presence of cross-sectional dependence, heteroskedasticity, and serial correlation lead us to use the Driscoll-Kraay Standard Errors. The results of these standard errors estimations are given together with the fixed effects estimations of the quadratic and cubic functional forms of this extended model.

7.6. ESTIMATION RESULTS FOR MODEL 3 (MODEL 3.2)

The previous model is combined with per capita energy use in this model. The panel data estimation techniques are used for 88 countries all over the world in the time period between 1980 and 2010. Model 3.2 for quadratic and cubic functional forms are as follows:

$$\ln(CO_2\_pc)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)_{it}^2 + \beta_4 D(lnENUSE\_pc)_{it} + u_{it}$$

$$\ln(CO_2\_pc)_{it} = \beta_{1i} + \beta_2 D(lnGDP\_pc)_{it} + \beta_3 D(lnGDP\_pc)_{it}^2 + \beta_4 D(lnGDP\_pc)_{it}^3 + \beta_5 D(lnENUSE\_pc)_{it} + u_{it}$$

These models are also estimated by using Pooled OLS, Fixed Effects, and Random Effects that can be attained in Appendix D.

The fixed effects model is more appropriate according to results of F-Test, Breusch Pagan LM Test, Hausman Test, and Sargan-Hansen Test. After that, the presence of cross-sectional dependence, heteroskedasticity, and autocorrelation are confirmed. As a result, the Driscoll-Kraay Standard Errors is carried out to overcome these problems. All tests for Model 3.2 can be accessed in Appendix E.

7.6.1. INTERPRETATION OF FIXED EFFECTS MODEL RESULTS FOR MODEL 3.2

As it is explained in previous part, it has been already decided to use fixed effects model depending on the tests' results. Table 7-25 exhibits the results of the fixed effects and Driscoll-Kraay Standard Errors estimations together. F statistics of the quadratic and cubic regressions suggest the rejection of the null hypothesis. It can be deduced that our extended models with per capita energy use variable fit the data well at %1 significance level. In addition to this, almost 0.97 R^2 values are quite good for both functional forms that can explain the reason for %97 of per capita CO_2 emissions.

The estimation results point out that all variables have significant association with ($lnCO_2\_pc$) except although their significance levels differ. When the Driscoll-Kraay Standard Errors model is carried out, all variables are still significant at quadratic form, whereas $D(lnGDP\_pc)^3$ become insignificant at cubic form. Per capita energy use has a positive sign meaning positive relationship between energy use and carbon emissions. In fact, %1 increase in per capita energy use causes nearly %0.35 rise in per capita CO_2 emission.

Table 7-25: Fixed Effects Model and Driscoll-Kraay Results for Model 3.2

Sample	**Quadratic FE**	**Driscoll-Kraay Standard Errors**	**Cubic FE**	**Driscoll-Kraay Standard Errors**
Cons	1.002*** (.005)	1.002*** (.031)	1.002*** (.005)	1.002*** (.032)
D(lnGDP_pc)	-1.137* (.689)	-1.137* (.614)	-5.411** (2.823)	-5.411* (3.750)
D(lnGDP_pc)^2	.081** (.038)	.081*** (.029)	.573** (.317)	.573* (.434)
D(lnGDP_pc)^3	-	-	-.018* (.012)	-.018 (.016)
D(lnENUSE_pc)	.348*** (.086)	.348*** (.086)	.334*** (.086)	.334*** (.081)
F-test	12.58	-	10.05	-
R-squared	0.974	0.015	0.974	0.016
Adj. R-sqr.	0.973	-	0.973	-
Observations	2640	2640	2640	2640
Countries	88	88	88	88

Note: Values in parentheses below coefficients are standard errors. ***, **, and * indicate significance at 1%, 5% and 10% levels.

Furthermore, signs of the coefficients exhibit U-shape relationship for quadratic functional form and it is supposed to reveal inverted N-shape relationship for cubic functional form if the variable (lnGDP_pc)^3 is individually significant. U-shaped curve means that CO_2 emissions decline as income increases until some point. After that it increases along with the increase in income. However, it is expected to decrease again as the inverted N-shaped curve implies. The insignificance of the variable (lnGDP_pc)^3 prevent this diminishing. That is why we can conclude that there is a U-shape relationship for both of the functional forms. As a result, the EKC does is not for this set of countries the year between 1980 and 2010.

CHAPTER 8

CONCLUSION AND DISCUSSION

In the last decades, studies about CO_2 emissions have been increasing due to concerns with the global climate change. CO_2 emissions, which of enormous amount are resulted from the combustion of fossil fuels, have been accelerating drastically after the industrial revolution and they clearly damage the environment. Most of the studies in the literature are empirical analyses to detect the relationship between economic growth and environmental degradation in the context of the EKC.

In this thesis, the relationship between per capita income and per capita CO_2 emissions is examined under three cases. The first one is for 26 high income OECD countries for the time periods between 1980 and 2010. The results of the panel data analysis show that the U-shaped curve for quadratic specification and inverted N-shaped one for cubic specification do not hold the EKC. The second case is for 52 emerging countries for the same time horizon. Quadratic equation analysis gives the U-shaped curve, while the cubic analysis results in the N-shaped curve. Hence, the EKC is not valid for this set of countries as well. Lastly, analyses for 88 countries over the same time span do not prove the existence for the EKC hypothesis because the U-shaped curve for quadratic form and inverted N-shaped one for cubic form are detected. Therefore, our data sets for three different cases reveal that the EKC is not valid.

Later on, all analyses for three different cases are carried out by adding the per capita energy use as an explanatory variable to check the energy, environment, and economic growth nexus with respect to the EKC. Both the first and the second cases demonstrate that the U-shaped curve for quadratic specification and the N-shaped curve for cubic specification do not support the existence of the EKC. Finally, the third case does not hold the validity of the EKC either; since the U-shapde curve for quadratic form and the inverted N-shaped curve for the cubic form are observed. Thereby, the EKC does not exist for these data sets. On the other hand, the per capita energy use is significant at 1% level for all cases and all polynomial specification. This may be a good indicator for the importance of including the energy use into the economic growth and environmental nexus.

Obviously, there is no statistical evidence in favor of the validity of the EKC for neither per capita CO_2 emissions and per capita income nor per capita CO_2 emissions, per capita income, and per capita energy use in three different cases. Results of our analysis do not confirm that CO_2 emissions increase along with the increase in income until the turning point and decline due to higher levels of income. If this is the case, it can be observed for the high income OECD countries at least because they should be the closest countries to the turning point. Besides, high income OECD countries, expect the US, ratified the Kyoto Protocol and they have a commitment to reduce their emissions level. However, the U-shaped curve proves the opposite; while inverted N-shaped curve displays that they are in a kind of cycle to decrease emissions level then increase it and then decrease it again. Moreover, N-shaped curve is an indication of insufficiency of environmentally friendly improvements. Therefore, depending on results of our analyses, policies for reducing the GHGs emissions like Kyoto Protocol seem insufficient.

These results do not confront with the studies in the EKC literature due to ambiguity of the results in the literature. The EKC can generally be observed for some pollutants such as SO_2, whereas this is not the case for every environmental indicators. There are many empirical studies carried out by a variety of parametric, semi-parametric, and nonparametric econometric techniques which do not support the EKC hypothesis for CO_2 emissions. Thus, results of our analyses should be perceived as one of the empirical analysis although they disprove the validity of the EKC.

Even if the validity of the EKC hypothesis is supported by our analyses, this is still a problem. The EKC hypothesis posits that the economic growth can be a remedy for environmental degradation; hence, the exploitation of natural resources for the sake of economic growth can be acceptable until reaching the turning point of the curve. However, irreversibility of the ecological damages is ignored with this perception. They may persist after reaching the specific income level. This persistence is crucial especially for CO_2 emissions and its long term impacts on environment. As a result, actions to slow down the release of CO_2 emissions should not wait until reaching high income levels or raising awareness about environmental concerns. Global, regional, and local policies are needed independently from the income level to combat climate change, or at least to adapt to climate change.

In addition, an increase in per capita income cannot be the only variable to reduce environmental degradation because environmental degradation is a complex issue, which cannot be thoroughly explained by per capita income, as it is stated above. There are other variables and factors affecting the pollution level such as environmental awareness, scale, composition, and technique effects, trade openness, environmental regulations, and institutional capacity. Moreover, individuals and households, national and international companies, business enterprises, non-governmental organizations and governments play crucial roles in the increase of environmental quality. Rising environmental awareness in societies which is interpreted as a drawback reveals itself costly in current economic system. That is why environmental issues are ignored by aforementioned institutions. However, it is better to bear in mind that this cost will be multiplied from generation to generation. Therefore, taking immediate actions such as rising awareness and enacting environmental regulations to reduce environmental degradation and to mitigate the climate change or at least adapt to climate change are vital even if it seems costly for the time being.

Furthermore, there are some limitations to our study. One of them is the availability of the data. There is an urge to constitute data especially for emerging countries. Data availability is more significant for local scale analysis to induce policy creations. Other than availability of the data, the quality of the data is doubtful for most of the countries. This problem should be overcome through the help of international organizations and institutions. Besides, more sophisticated econometric techniques can be applied to obtain better and more reliable results. For instance, panel cointegration can be applied for different data sets so that long term relationship can be observed and elaborated thoroughly. Adding structural breaks to these analyses may be other motivation for further studies. In addition to parametric estimation techniques, semi-parametric and nonparametric methods can be preferred to apply different data sets. Moreover, GDP per capita may not be the only factor affecting the environmental quality as it is stated before. Using various indexes instead of GDP per capita as an economic development indicator or adding different variables such as trade openness, population density, and education level may result in better outcomes for policy recommendations. Therefore, this analysis can be improved in terms of data sets, econometric techniques, and variables used in analysis.

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APPENDIX A

THE LITERATURE REVIEW OF THE EKC STUDIES

Table A-1: The literature review of the EKC studies.

AIR POLLUTANTS					
Authors & Publication Year	**Environmental Indicators**	**Economic Indicators & Other Variables**	**Regions & Periods**	**Econometric Technique**	**Results**
Grossman & Krueger (1991)	Sulphur Dioxide (SO_2) and dark matter suspended	GDP per capita (cap), characteristics of the site and city and time trend, lagged GDP	A cross-section of urban areas in 42 countries (Each indicator has different time periods)	Panel data, Cubic in logs, Random effect model (REM)	Inverted U-shape relationship
Panayotou (1993)	SO_2, Nitrogen Oxides(NO_x), SPM, Deforestation	GDP per cap, population density, interaction between per capita and population density	Developing and developed countries, cross section in the late 1980	Cross-sectional data; Translog, log-log, quadratic; OLS	Inverted U-shape relationship
Selden & Song (1994)	SO_2, NOx, SPM, CO	GDP per cap and population density	A cross-national panel data; 1952-1985	Quadratic, Cubic; Pooled OLS, Fixed effect (FE) and REM	Inverted U-shape relationship
Shafik & Bandyopad-hyay (1994)	CO_2 emissions per cap; annual and total deforestation; SO_2, SPM; DO, lack of clean water and urban sanitation, municipal waste per cap	GDP per cap in PPP, a time trend	149 countries, 1960-1990	Panel data, Log - Linear, Quadratic and Cubic; FE	Inverted U-shape relationship for SO2 and SPM; Monotonic positive relationships for others

Table A-1: Continued

Grossman & Krueger (1995)	SO_2, SPM and Various water pollutants: Dissolved Oxygen (DO), Nitrate, Bacteria	GDP per cap, a three-year average of lagged per capita GDP and a vector of other covariates as a dummy variable	A cross-section of urban areas in 42 countries (Each indicator has different time periods.)	Panel Data, Quadratic, Cubic, Generalized Least Squares (GLS)	N-shape relationship for all but Inverted U-shape relationship for Nitrate
Cole, Rayner & Bates (1997)	SO_2, NO_x, CO, CO_2, SPM, CFCs, municipal wastes	GDP per cap, trade intensity, population density, time trend	11 OECD countries; 1970-1992	Both level and log, Quadratic; OLS and GLS, FE and REM	Inverted U-shape relationship except for CFCs and municipal wastes
De Bruyn (1997)	SO_2	GDP per cap	West Germany and Netherlands; 1980s	Reduced form, Decomposition analysis	Find SO_2deduction in West Germany and Netherlands is a result of technology innovation
Panayotou (1997)	SO_2	GDP per cap, population density, industrial share, GDP growth, policy	30 developing and developed countries; 1982-1994	Panel data, Level, Cubic, FE	N-Shape relationship
Vincent (1997)	Total Suspended Particulate (TSP), CO, SO_2, NO_x; BOD, COD, ammoniacal nitrogen, pH and suspended solids	GDP per cap, population density	Malaysia; 1977-1991	Panel data, cubic; FE and RE	No significant relationship for BOD, COD, and suspended solids; linear relationship with positive slope for others

Table A-1: Continued

Kaufmann, Davidsdottir,Garnham & Pauly (1998)	SO_2	GDP per capita, population density, economic activity and Iron and steel exports	23 countries; 1974-1989	Level, Quadratic, and Cubic; GLS with FE and REM	Inverted U-shape relationship
De Bruyn, van den Bergh & Opschoor (1998)	SO_2, NO_x, CO_2	GDP per capita and price of input related factors	Netherlands, West Germany, UK and USA; various time intervals between 1960-1993	OLS, each country separately estimated, Decomposition Analysis	Linear relationship
Torras & Boyce (1998)	SO_2, SPM, DO, Access to clean water and sanitation, fecal coliform	GDP per cap with PPP, GINI, literacy, political right and civil liberty, urbanization	287 stations in 58 countries (GEMS); 1977-1991	Level, cubic, OLS	N-shape relationship
Barrett & Graddy (2000)	SO_2	GDP per cap, Lag income is included	27-52 cities in 14-32 countries; 1977, 1982, 1988	Panel data, Level, Cubic; RE with GLS	N-shape relationship
Harbaugh. Levinson & Wilson (2001)	SO_2, smoke, and TSP	GDP per capita, 3-year average of lagged per capita GDP, population density, trade intensity, democracy index	Similar case of Grossman &Krueger, but 10 years of extended data and 4 more countries were added from the database	Panel data, Log-Level, Cubic; GLS with FE and RE	Little empirical support for an inverted-U-shape relationship
Roca, Padilla, Farré & Galletto (2001)	SO_2	GDP per cap, share of nuclear power and coal in total primary energy	Spain, 1973-1996	Time series, log, cointegration	Monotonically decreasing relationship

Table A-1: Continued

Millimet, List & Stengos (2003)	SO_2, NO_x	GDP per capita	48 US state; 1929-1994	Semi-parametrical Partially Linear Regression(PLR) model	Inverted U-shape relationship
Perman & Stern (2003)	SO_2	GDP with PPP, population	74 countries; 1960-1990	Level, Quadratic, Cointegration for each country separately	Monotonically increasing or U-shape relationship very often
Cole (2004)	SO_2, SPM, NOx, carbon monoxide (CO); DO, BOD, Nitrates, Total Phosphorus (TP); CO_2	GDP per cap, share of manufacturing in GNP, share of pollution intensive exports and imports in total exports and imports, trade intensity	21 OECD countries; 1980-1997	Panel data, log, cubic; GLS - RE and FE	Inverted U-shape relationship for CO_2, inverted U-shape and inverted N-shape relationships for other pollutants
Akbostancı, Türüt-Aşık & Tunç (2009)	SO_2, SPM, CO_2	GDP per cap, population density	Turkey; 1968–2003 - time series model; 1992-2001 - panel data model (provinces base)	time series-Johansen cointegration, panel data-GLS, level and log; cubic	N-shape relationship for $SO_2$and SPM; monotonically increasing relationship for CO_2
Burnett (2009)	SO_2, CO, lead, Nitrogen Dioxide (NO_2), SPM, ground level ozone (O_3), average direct solar radiation, precipitation, average temperature, opacity of cloud cover, relative humidity, and average wind speed	real GDP, socioeconomic and meteorological covariates	United States (100 metropolitan statistical areas), 2001-2005	Panel data, log-level, Quadratic; FE models	Inverted U-shape relationship for SO_2, U-shape relationship for O_3, monotonically decreasing relationship for others

Table A-1: Continued

Eicher & Begun (2012)	SO_2	GDP, GNP, Investment, trade, capital intensity, population density, education, temperature, precipitation variation	44 countries; 1971-2006	Log-level; cubic; FE model, (Bayesian Model Averaging)	weak evidence for an EKC
WATER POLLUTANTS					
Shafik & Bandyopad-hyay(1994)	CO_2 emissions per cap; annual and total deforestation; SO_2, SPM; DO, lack of clean water and urban sanitation, municipal waste per cap	GDP per cap in PPP, a time trend	149 countries, 1960-1990	Panel data, Log - Linear, Quadratic and Cubic; FE	Inverted U-shape relationship for $SO_2$and SPM; Monotonic positive relationships for others
Grossman & Krueger (1995)	SO_2, SPM and Various water pollutants: Dissolved Oxygen (DO), Nitrate, Bacteria	GDP per cap, a three-year average of lagged per capita GDP and a vector of other covariates as a dummy variable	A cross-section of urban areas in 42 countries (Each indicator has different time periods.)	Panel Data, Quadratic, Cubic; GLS	N-shape relationship but inverted U-shape relationship for Nitrate
Cole, Rayner & Bates (1997)	SO_2, NO_x, CO, CO_2, SPM, CFCs, municipal wastes	GDP per cap, trade intensity, population density, time trend	11 OECD countries; 1970-1992	Both level and log, Quadratic; OLS and GLS, FE and REM	Inverted U-shape except for CFCs and municipal wastes
Vincent (1997)	Total Suspended Particulate,CO, SO_2, NO_x; BOD, COD, ammoniacal nitrogen, pH and suspended solids	GDP per cap, population density	Malaysia; 1977-1991	Panel data, cubic; FE and RE	no significant relationship for BOD, COD, and suspended solids; linear with positive slope for others

Table A-1: Continued

Guo & Yang (2003)	COD, Total Phosphate (TOTP)	GDP per cap in PPP	71 water quality stations at Lower Mekong Basin (at transnational border) 1985-2000	Panel data, log-log, quadratic; Least Squares Dummy Variable (LSDV)	No significant relationship
Cole (2004)	SO_2, SPM, NOx, carbon monoxide (CO); DO, BOD, Nitrates, Total Phosphorus (TP); CO_2	GDP per cap, share of manufacturing in GNP, share of pollution intensive exports and imports in total exports and imports, trade intensity	21 OECD countries; 1980-1997	Panel data, log, cubic; GLS - RE and FE	Inverted U-shape relationship for CO_2, inverted U-shape and inverted N-shape relationship for other pollutants
Paudel, Zapata & Susanto (2005)	DO, P, Nitrates	GDP per capita, population density	53 parishes in Louisiana: 1985-1999	Panel data, quadratic, cubic; both parametric (FE and REM) and semiparametric models	Parametric: Inverted U-shape relationship for quadratic and N-shape relationship for cubic. Semiparametric: quadratic curve for N, inverse quadratic curve for DO, ambiguous result for P
Granda, Pérez & Muñoz (2008)	BOD	GDP per cap, foreign trade intensity	46 countries; 1980-2000	Panel data, log-log, quadratic; Panel Cointegration	The EKC does not exist for this set of countries
Archibald, Bochniarz, Gemma & Srebotnjak (2009)	BOD	GDP per capita, 3year average of lagged per capita income, FDI, EBRD's liberalization index, population density	25 Countries in Central and Eastern Europe; 1992-2005	Panel data, level, cubic; FE	Inverted N-shape relationship

Table A-1: Continued

Barua & Hubacek (2009)	BOD, COD	GDP per cap	16 states in India; 1981-2000	Time series for each state, Cubic, level, OLS	4 states: inverted U-shape relationship, 6 states: N-shape relationship, 2 states: U-shape relationship, 4 states: no significant relationship
Lee, Chiu & Sun (2010)	BOD	GDP per cap, trade openness (the ratio of exports and imports of goods and services to real GDP) and population density	97 countries divided into 4 groups (Asia and Oceania are together); 1980-2001	Panel data, cubic, level; Generalized Method of Moments (GMM)	Inverted U-shape relationship for America and Europe, but nor for Africa, Asia, and Oceania
Wong & Lewis (2013)	TP, DO, Nitrates, Ammoniacal nitrogen in water (Ammonium)	GDP per capita, Foreign direct investment (FDI), the value added by the industrial sector as a percentage of GDP	Thailand, Vietnam, Lao PDR and Cambodia along Mekong main stream; 1985-2009 (except Cambodia, from 1993 to 2009)	Cubic, Quadratic; FE and REM	Quadratic - TP: inverted U-shape, DO: U-shape, Nitrates: not statistically significant, Ammonium: inverted U-shape. Cubic - TP, DO and Nitrates: N-shape, Ammonium: not statistically significant.
OTHER ENVIRONMENTAL INDICATORS					
Shafik & Bandyopad-hyay (1992)	Deforestation; CO_2; Water pollutants (DO and fecal coliforms)	GDP per cap, a time trend	149 countries, 1961-1986	Panel data, log-log, quadratic and cubic; FE	Inverted U-shape relationship; insignificant relationship
Hettige, Lucas & Wheeler (1992)	Toxic intensity of manufacturing	GDP per cap, interaction between per capita and time	80 countries; 1960 - 1988	Panel data, Log, Quadratic, OLS	Inverted U-shape relationship

Table A-1: Continued

Panayotou (1993)	SO_2, NO_x, SPM, Deforestation	GDP per cap, population density, interaction between per capita and population density	Developing and developed countries, cross section in the late 1980	Cross-sectional data; Translog, log-log, quadratic; OLS	Inverted U-shape relationship
Shafik & Bandyopad-hyay (1994)	CO_2 emissions per cap; annual and total deforestation; SO_2, SPM; DO, lack of clean water and urban sanitation, municipal waste per cap	GDP per cap in PPP, a time trend	149 countries, 1960-1990	Panel data, Log - Linear, Quadratic and Cubic; Fixed Effect (FE)	Inverted U-shape relationship for $SO_2$and SPM; Monotonic positive relationships for others
Cropper & Griffiths (1994)	Deforestation	Per cap income, population density, percentage change in income and population, price of deforestation	Latin America, Asia and Africa; 1961-1988	Panel data, level, quadratic; FE with Paris Winsten technique	Inverted U-shape relationship for America and Africa but not applicable for Asia
Panayotou (1997)	The quality of policies and institutions reduce environmental degradation at low income and speed up improvement at high income	GDP per cap, population density, annual growth rate, policy variable and interaction variables	30 developing and developed countries: 1982-1994	Level, Quadratic, and Cubic; GLS with FE and RE and Decomposition analysis with Reduced form	Inverted U-shaped, J-shaped, and N-shaped curves
Taskin & Zaim (2000)	Environmental efficiency index based on CO_2 emissions	GDP per capita	52 countries: 1975-1990	Nonparametric production frontier technique (kernel estimation)	Inverted U-shape relationship for the countries having GDP per capita over $5000

Table A-1: Continued

Canas, Ferrao & Conceicao (2003)	direct material input per cap	GDP per cap	16 industrialized countries: 1960-1998	Panel data, level, quadratic, cubic; FE and REM	Inverted U-shape relationship for quadratic and N-shape relationship for cubic
Jha & Murthy (2003)	Environmental Degradation Index (EDI)	Human Development Index (HDI)	174 countries: 1990-1996	Principle Component Analysis then panel data, level, cubic; FE and RE	Inverted N-shape relationship
Caviglia-Harris, Chambers & Kahn (2009)	Ecological Footprint (EF)	GDP per cap, population, country specific effect and time-specific effects	146 countries: 1961-2000, 5years time periods	Panel data, log-log, quadratic; FE and REM	No inverted U-shape relationship
Tsuzuki (2009)	Pollution discharge for BOD, TP, Total Nitrogen	GDP per cap	7 developing countries; 1998-2002	Multiple linear regression and principle component analysis	Inverted U-shape relationship for both BOD and TP; monotonically decreasing relationship for Nitrates
Fan & Zheng (2013)	Environmental Pollution Index	per cap GDP index	Sichuan province in China; 1985-2010	Level, Quadratic and Cubic; OLS	U-shape relationship for quadratic, Inverted N-shape relationship for cubic

Table A-1 exhibits the literature review of the EKC studies. The name of the author(s), the publication year, environmental and economic indicators, study areas such as countries and cross countries, time periods, used econometric estimation techniques, and the results of the studies are listed in the Table A-1.

APPENDIX B

LIST OF COUNTRIES IN ANALYSES

Table B-1: List of the countries used in the analysis

	High-income OECD Countries	**Emerging Countries**	**All Countries**
1	Australia	Albania	Albania
2	Austria	Algeria	Algeria
3	Belgium	Argentina	Argentina
4	Canada	Bangladesh	Australia
5	Denmark	Bolivia	Austria
6	Finland	Brazil	Bahrain
7	France	Bulgaria	Bangladesh
8	Germany	Cameroon	Belgium
9	Greece	Chile	Bolivia
10	Hungary	China	Brazil
11	Iceland	Colombia	Bulgaria
12	Ireland	Congo, Dem. Rep.	Cameroon
13	Israel	Costa Rica	Canada
14	Italy	Cote d'Ivoire	Chile
15	Japan	Dominican Republic	China
16	South Korea	Ecuador	Colombia
17	Luxembourg	Egypt	Congo, Dem. Rep.
18	Netherlands	Ethiopia	Costa Rica
19	New Zealand	Ghana	Côte d'Ivoire
20	Norway	Guatemala	Cyprus
21	Portugal	India	Denmark
22	Spain	Indonesia	Dominican Republic
23	Sweden	Iran	Ecuador
24	Switzerland	Iraq	Egypt
25	United Kingdom	Jamaica	Ethiopia
26	United States	Jordan	Finland
27		Kenya	France
28		Malaysia	Germany
29		Mexico	Ghana
30		Morocco	Greece
31		Mozambique	Guatemala
32		Nigeria	Hong Kong
33		Pakistan	Hungary
34		Peru	Iceland
35		Philippines	India
36		Poland	Indonesia
37		Romania	Iran
38		Senegal	Iraq
39		South Africa	Ireland
40		Sri Lanka	Israel
41		Sudan	Italy

Table B-1: Continued

42		Syrian Arab Republic	Jamaica
43		Tanzania	Japan
44		Thailand	Jordan
45		Tunisia	Kenya
46		Turkey	Luxembourg
47		Uruguay	Malaysia
48		Venezuela	Malta
49		Vietnam	Mexico
50		Yemen	Morocco
51		Zambia	Mozambique
52		Zimbabwe	Netherlands
53			New Zealand
54			Nigeria
55			Norway
56			Oman
57			Qatar
58			Pakistan
59			Peru
60			Philippines
61			Poland
62			Portugal
63			Romania
64			Saudi Arabia
65			Senegal
66			Singapore
67			South Africa
68			South Korea
69			Spain
70			Sri Lanka
71			Sudan
72			Sweden
73			Switzerland
74			Syrian Arab Republic
75			Tanzania
76			Thailand
77			Trinidad & Tobago
78			Tunisia
79			Turkey
80			United Arab Emirates
81			United Kingdom
82			United States
83			Uruguay
84			Venezuela
85			Vietnam
86			Yemen
87			Zambia
88			Zimbabwe

APPENDIX C

UNIT ROOT TESTS

There are several panel unit root tests in order to determine the integration of panel series. Instead of the first generation unit root tests, it makes more sense to use the second generation unit root tests, which take into account the cross-sectional dependency, since there exist cross-sectional dependency among variables. Lewandowski (2006) determined that one of the second generation unit root tests is Pesaran CADF proposed for panels with cross-section dependence. The null hypothesis of the test is that all series are non-stationary. According to results shown at Table C-1, we fail to reject the null hypothesis for high-income OECD countries, except the dependent variable the natural logarithm of per capita CO_2 emission and the independent variable the natural logarithm of per capita energy use. Hence, the first difference of the variables should be taken. When the first difference of the GDP per capita is taken, it can be called as GDP per capita growth rate as well. Besides, they are called as I(1), whereas $lnCO_2$_pc and lnENUSE_pc are labeled as I(0).

Table C-1: Pesaran CADF Test Results for high-income OECD Countries

Method Pesaran CADF	ln(GDP_pc)	$(lnGDP\_pc)^2$	$(lnGDP\_pc)^3$	ln(ENUSE_pc)	$lnCO_2$_pc
Lags(0)	-1.658	-1.642	-1.627	-2.302	-2.384
	[0.729]	[0.757]	[0.780]	[0.002]	[0.000]
Lags(1)	-2.038	-2.016	-1.995	-2.290	-2.220
	[0.073]	[0.091]	[0.111]	[0.002]	[0.007]
Lags(2)	-1.531	-1.519	-1.510	-2.174	-1.989
	[0.903]	[0.913]	[0.921]	[0.014]	[0.118]
Result	I(1)	I(1)	I(1)	I(0)	I(0)

Table C-2 displays the unit root test results for 52 emerging countries, we fail to reject the null hypothesis, except the dependent variable the natural logarithm of per capita CO_2 emissions. Therefore, the first difference of the variables should be taken to get rid of the non-stationary. They are all called as I(1), while $lnCO_2$_pc is labeled as I(0).

Table C-2: Pesaran CADF Test Results for Emerging Countries

Method Pesaran CADF	ln(GDP_pc)	$(lnGDP\_pc)^2$	$(lnGDP\_pc)^3$	ln(ENUSE_pc)	$lnCO_2$_pc
Lags(0)	-1.353	-1.351	-1.345	-1.985	-2.062
	[0.999]	[0.999]	[0.999]	[0.049]	[0.012]
Lags(1)	-1.595	-1.600	-1.601	-1.899	-2.062
	[0.910]	[0.904]	[0.903]	[0.162]	[0.012]
Lags(2)	-1.427	-1.433	-1.436	-1.545	-2.009
	[0.996]	[0.995]	[0.995]	[0.958]	[0.033]
Result	I(1)	I(1)	I(1)	I(1)	I(0)

Table C-3 exhibits the unit root test results for all 88 countries, we fail to reject the null hypothesis, except the dependent variable the natural logarithm of per capita CO_2 emissions. Therefore, the first difference of the variables should be taken to get rid of the non-stationary. They are called as I(1), while $lnCO_2$_pc is labeled as I(0).

Table C-3: Pesaran CADF Test Results for All Countries

Method Pesaran CADF	ln(GDP_pc)	$(lnGDP\_pc)^2$	$(lnGDP\_pc)^3$	ln(ENUSE_pc)	$lnCO_2$_pc
Lags(0)	-1.387	-1.411	-1.429	-1.874	-2.039
	[1.000]	[1.000]	[1.000]	[0.150]	[0.004]
Lags(1)	-1.861	-1.893	-1.918	-1.958	-2.182
	[0.182]	[0.109]	[0.070]	[0.030]	[0.000]
Lags(2)	-1.704	-1.729	-1.749	-1.619	-2.086
	[0.745]	[0.660]	[0.582]	[0.934]	[0.001]
Result	I(1)	I(1)	I(1)	I(1)	I(0)

APPENDIX D

POOLED, FE, AND RE ANALYSES TOGETHER

Table D-1: Pooled OLS, FE, and RE for quadratic form of Model 1.1

Variable	pooled	fixed	random
D(lnGDP_pc)	-50.263442***	-50.263442***	-50.863264***
$D(lnGDP\_pc)^2$	2.4467165***	2.4467165***	2.4762984***
Austria		-.702679***	
Belgium		-.38850545***	
Canada		-0.0117018	
Denmark		-.44662446***	
Finland		-.37667833***	
France		-.89137879***	
Germany		-.38130274***	
Greece		-.75744221***	
Hungary		-.91342029***	
Iceland		-.53296341***	
Ireland		-.51695393***	
Israel		-.68923861***	
Italy		-.81159554***	
Japan		-.57766399***	
South Korea		-.61625945***	
Luxembourg		.32216619***	
Netherlands		-.45106243***	
New Zealand		-.79317488***	
Norway		-.62765999***	
Portugal		-1.2354341***	
Spain		-.93645847***	
Sweden		-.91886358***	
Switzerland		-.98254686***	
United Kingdom		-.56093544***	
United States		.13094122***	
_cons	2.2548287***	2.8189609***	2.25473***
N	780	780	780
r2	0.18511405	0.89493221	
r2_a	0.15585618	0.89115983	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-2: Pooled OLS, FE, and RE for cubic form of Model 1.1

Variable	pooled	fixed	random
D(lnGDP_pc)	-545.51526***	-545.51526***	-541.32631***
$D(lnGDP\_pc)^2$	51.841016***	51.841016***	51.398825***
$D(lnGDP\_pc)^3$	-1.638116***	-1.638116***	-1.6226545***
Austria		-.7047049***	
Belgium		-.3918056***	
Canada		-0.01075343	
Denmark		-.4502023***	
Finland		-.3876684***	
France		-.89614298***	
Germany		-.38552561***	
Greece		-.76935301***	
Hungary		-.91315736***	
Iceland		-.52985735***	
Ireland		-.53757806***	
Israel		-.70350386***	
Italy		-.81711757***	
Japan		-.58606795***	
South Korea		-.53754513***	
Luxembourg		.40440015***	
Netherlands		-.45109328***	
New Zealand		-.80238226***	
Norway		-.60643597***	
Portugal		-1.2429459***	
Spain		-.95114629***	
Sweden		-.92102752***	
Switzerland		-.97295195***	
United Kingdom		-.57088823***	
United States		.14070919***	
_cons	2.2515273***	2.8128636***	2.2514497***
N	780	780	780
r2	0.30616942	0.91054055	
r2_a	0.2803009	0.90720518	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-3: Pooled OLS, FE, and RE for quadratic form of Model 1.2

Variable	pooled	fixed	random
D(lnGDP_pc)	-3.8380552	-3,8380552	-4,0270242
D(lnGDP_pc)^2	0.19592464	0,19592464	0,20524986
(lnENUSE_pc)	.75322377***	.75322377***	.75027447***
Austria		-.39775695***	
Belgium		-.38398158***	
Canada		-.31658787***	
Denmark		-.17734621***	
Finland		-.49723547***	
France		-.68965326***	
Germany		-.23477719***	
Greece		-.13160961***	
Hungary		-.43178704***	
Iceland		-1.002293***	
Ireland		-.14779531***	
Israel		-.18331701***	
Italy		-.33495198***	
Japan		-.31950272***	
South Korea		-.33815072***	
Luxembourg		0.03392971	
Netherlands		-.3468478***	
New Zealand		-.58935752***	
Norway		-.62808872***	
Portugal		-.49677659***	
Spain		-.41443078***	
Sweden		-.96740622***	
Switzerland		-.67166557***	
United Kingdom		-.2979063***	
United States		-.15261794***	
_cons	-4.0038971***	-3.6147466***	-3.9794523***
N	780	780	780
r2	0.72473196	0.96450816	
r2_a	0.71446897	0.96318489	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-4: Pooled OLS, FE, and RE for cubic form of Model 1.2

Variable	pooled	fixed	random
D(lnGDP_pc)	-103.90965***	-103.90965***	-104.4315***
D(lnGDP_pc)^2	10.088412***	10.088412***	10.133379***
D(lnGDP_pc)^3	-.32530746***	-.32530746***	-.32656603***
(lnENUSE_pc)	.72529598***	.72529598***	.72323937***
Austria		-.40946507***	
Belgium		-.38480468***	
Canada		-.30509507***	
Denmark		-.18804093***	
Finland		-.49494797***	
France		-.69807888***	
Germany		-.24104862***	
Greece		-.15717935***	
Hungary		-.44959266***	
Iceland		-.98427454***	
Ireland		-.16557853***	
Israel		-.20490829***	
Italy		-.35372142***	
Japan		-.33074365***	
South Korea		-.33283076***	
Luxembourg		.06094739**	
Netherlands		-.35071796***	
New Zealand		-.59874305***	
Norway		-.62385802***	
Portugal		-.52565605***	
Spain		-.43670315***	
Sweden		-.9660361***	
Switzerland		-.68128691***	
United Kingdom		-.3096353***	
United States		-.14016444***	
_cons	-3.7724937***	-3.3774104***	-3.7554678***
N	780	780	780
r2	0.72876412	0.96502805	
r2_a	0.71827633	0.9636758	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-5: Pooled OLS, FE, and RE for quadratic form of Model 2.1

Variable	pooled	fixed	random
D(lnGDP_pc)	-3.2491887**	-3.2491887**	-3.324552**
D(lnGDP_pc)^2	.21929738**	.21929738**	.22385037**
Albenia		.76373229***	
Bulgaria		1.0455901***	
Poland		-2.1059682***	
Romania		-.19633923**	
Bangladesh		.271652***	
China		1.7730051***	
India		-1.0464576***	
Indonesia		.86339382***	
Malaysia		.75090061***	
Pakistan		.16012018*	
Philippines		-0.10045526	
Sri Lanka		-1.3579724***	
Thailand		-2.9314709***	
Vietnam		.19477235**	
Bolivia		.28600078***	
Brazil		.30705595***	
Chile		-3.3205263***	
Colombia		-1.5569876***	
Costa Rica		-.68153295***	
Dominican Republic		-.38966685***	
Ecuador		-.19467524**	
Guatemala		1.2198202***	
Jamaica		1.122765***	
Mexico		.945777***	
Peru		.90222358***	
Uruguay		-1.4463442***	
Venezuela		1.1114936***	
Iran		1.0209355***	
Iraq		-0.13715654	
Jordan		-2.4602695***	
Syrian Arab Republic		-.63013836***	
Yemen		-.70787716***	
Algeria		-.16723368*	
Cameroon		-.50066066***	
Côte d'Ivoire		1.8840454***	
DR Congo		1.5120668***	
Egypt		-1.1984579***	
Ethiopia		1.7107479***	
Ghana		-1.1465832***	
Kenya		-1.6632255***	
Morocco		.75823485***	
Mozambique		-2.6235785***	
Nigeria		.41277137***	
Senegal		.40839514***	

Table D-5: Continued

South Africa		.81409444***	
Sudan		0.14207851	
Tanzania		1.4935701***	
Tunisia		-.84011827***	
Zambia		-.54173462***	
Zimbabwe		-1.4876526***	
Argentina		-0.09918449	
_cons	.10701201***	.25426249***	0.10701993
N	1560	1560	1560
r2	0.01099028	0.95187513	
r2_a	-0.02381551	0.95018149	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-6: Pooled OLS, FE, and RE for cubic form of Model 2.1

Variable	pooled	fixed	random
DLGDP	8.1036814	8.1036814	8.2506407
DLGDP2	-1.2953495	-1.2953495	-1.3206383
DLGDP3	0.06583348	0.06583348	0.06713711
Albenia		.76076675***	
Bulgaria		1.0399715***	
Poland		-2.1040443***	
Romania		-.19834159**	
Bangladesh		.26749059***	
China		1.766845***	
India		-1.0492883***	
Indonesia		.85420548***	
Malaysia		.75981135***	
Pakistan		.15662968*	
Philippines		-0.10741511	
Sri Lanka		-1.3662993***	
Thailand		-2.932201***	
Vietnam		.18923479*	
Bolivia		.28273562***	
Brazil		.30900639***	
Chile		-3.3238406***	
Colombia		-1.5558847***	
Costa Rica		-.68452835***	
Dominican Republic		-.3826266***	
Ecuador		-.19084012**	

Table D-6: Continued

Guatemala		1.2127555***	
Jamaica		1.136781***	
Mexico		.94200856***	
Peru		.90011123***	
Uruguay		-1.4486618***	
Venezuela		1.1029596***	
Iran		1.0154249***	
Iraq		-0.13578259	
Jordan		-2.4638095***	
Syrian Arab Republic		-.6301149***	
Yemen		-.70464396***	
Algeria		-.17092185*	
Cameroon		-.50192023***	
Côte d'Ivoire		1.8714254***	
DR Congo		1.5080634***	
Egypt		-1.2001109***	
Ethiopia		1.7071717***	
Ghana		-1.1414431***	
Kenya		-1.661832***	
Morocco		.75734361***	
Mozambique		-2.624482***	
Nigeria		.41280197***	
Senegal		.40726656***	
South Africa		.80811322***	
Sudan		0.13503053	
Tanzania		1.490785***	
Tunisia		-.83258207***	
Zambia		-.54049663***	
Zimbabwe		-1.4912764***	
Argentina		-0.09893923	
_cons	.10830518***	.25729725***	0.10833875
N	1560	1560	1560
r2	0.01289999	0.95196805	
r2_a	-0.02251755	0.95024465	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-7: Pooled OLS, FE, and RE for quadratic form of Model 2.2

Variable	pooled	fixed	random
DLGDP	-3.080479*	-3.080479*	-3.1581934*
DLGDP2	.20086525**	.20086525**	.20551432**
DLENUSE	.39147673**	.39147673**	.39364184**
Albenia		.74607109***	
Bulgaria		1.0334037***	
Poland		-2.1225266***	
Romania		-.21165658**	
Bangladesh		.25811297***	
China		1.7689813***	
India		-1.0539162***	
Indonesia		.84834907***	
Malaysia		.73536513***	
Pakistan		.15198395*	
Philippines		-0,11580158	
Sri Lanka		-1.3727149***	
Thailand		-2.9440264***	
Vietnam		.1865715*	
Bolivia		.27332946***	
Brazil		.28705494***	
Chile		-3.3287979***	
Colombia		-1.5666409***	
Costa Rica		-.69469088***	
Dominican Republic		-.40432606***	
Ecuador		-.21165063**	
Guatemala		1.1988467***	
Jamaica		1.0979921***	
Mexico		.9366595***	
Peru		.88645242***	
Uruguay		-1.4569561***	
Venezuela		1.0927756***	
Iran		1.0105339***	
Iraq		-.15438167*	
Jordan		-2.4647592***	
Syrian Arab Republic		-.63910933***	
Yemen		-.72113968***	
Algeria		-.17582488*	
Cameroon		-.50857352***	
Côte d'Ivoire		1.8816137***	
DR Congo		1.509584***	
Egypt		-1.2072078***	
Ethiopia		1.6993162***	
Ghana		-1.1579358***	
Kenya		-1.6690214***	
Morocco		.74057646***	
Mozambique		-2.6329793***	
Nigeria		.39163241***	
Senegal		.39453791***	

Table D-7: Continued

South Africa		.79873206***	
Sudan		0,1310227	
Tanzania		1.481986***	
Tunisia		-.85724928***	
Zambia		-.56070523***	
Zimbabwe		-1.4949539***	
Argentina		-0,10604696	
_cons	.10489277***	.26435639***	0,10488942
N	1560	1560	1560
r2	0,01626278	0,95213169	
r2_a	-0,0190341	0,95041415	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-8: Pooled OLS, FE, and RE for cubic form of Model 2.2

Variable	pooled	fixed	random
DLGDP	8.7654573	8.7654573	8.9185433
DLGDP2	-1.3794987	-1.3794987	-1.4056279
DLGDP3	0.06867698	0.06867698	0.07001405
DLENUSE	.39776465**	.39776465**	.40008079**
Albenia		.74269379***	
Bulgaria		1.0273466***	
Poland		-2.1207855***	
Romania		-.21399145**	
Bangladesh		.25355436***	
China		1.7624904***	
India		-1.056989***	
Indonesia		.83852222***	
Malaysia		.74441122***	
Pakistan		.148212*	
Philippines		-0.12330853	
Sri Lanka		-1.3816382***	
Thailand		-2.9449897***	
Vietnam		.18066303*	
Bolivia		.26971975***	
Brazil		.28876836***	
Chile		-3.3323883***	
Colombia		-1.5656455***	
Costa Rica		-.698027***	
Dominican Republic		-.39721718***	
Ecuador		-.20792252**	
Guatemala		1.1911399***	
Jamaica		1.1122157***	
Mexico		.93258184***	
Peru		.88399552***	

Table D-8: Continued

Uruguay		-1.4595443***	
Venezuela		1.0835722***	
Iran		1.0046181***	
Iraq		-.15322506*	
Jordan		-2.4685242***	
Syrian Arab Republic		-.63922894***	
Yemen		-.71797986***	
Algeria		-.17981034*	
Cameroon		-.51001458***	
Côte d'Ivoire		1.8684096***	
DR Congo		1.5053678***	
Egypt		-1.2090727***	
Ethiopia		1.6954019***	
Ghana		-1.152756***	
Kenya		-1.6676608***	
Morocco		.73936309***	
Mozambique		-2.6340729***	
Nigeria		.39132479***	
Senegal		.39313801***	
South Africa		.79224574***	
Sudan		0.12349273	
Tanzania		1.4788945***	
Tunisia		-.84966274***	
Zambia		-.55971848***	
Zimbabwe		-1.4988515***	
Argentina		-0.10590134	
_cons	.10620776***	.26768436***	0.1062296
N	1560	1560	1560
r2	0.01833967	0.95223275	
r2_a	-0.01755882	0.95048594	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-9: Pooled OLS, FE, and RE for quadratic form of Model 3.1

Variable	pooled	fixed	random
DLGDP	-1.028479	-1,028479	-1.0766108
DLGDP2	.081856*	.081856*	.08453718*
Belgium		.76126488***	
Cyprus		1.0450578***	
Denmark		2.5645018***	
Finland		1.8590695***	
France		2.9072662***	
Germany		-2.1172251***	
Greece		2.1706816***	
Iceland		-.19925363**	
Ireland		.27074838***	
Italy		1.7741434***	
Luxembourg		-1.0498623***	
Malta		2.5523704***	
Netherlands		.86897318***	
Norway		.745823***	
Portugal		.16047853*	
Spain		-0,09841538	
Sweden		1.5720494***	
Switzerland		-1.3588212***	
Turkey		-2.9317547***	
United Kingdom		2.1113616***	
Canada		.19828315**	
United States		.28405268***	
Australia		.30479099***	
New Zealand		-3.3295965***	
Albania		2.1700838***	
Bulgaria		1.6630794***	
Hungary		2.1757331***	
Poland		-1.5625211***	
Romania		1.775988***	
Bangladesh		-.68414294***	
China		1.4724446***	
Hong Kong		1.6174003***	
India		2.0335952***	
Indonesia		-.39877064***	
Japan		-.19834136**	
Malaysia		1.2220494***	
Pakistan		1.1034198***	
Philippines		1.9900127***	
Singapore		1.8410629***	
South Korea		1.7397031***	
Sri Lanka		.94379696***	
Thailand		1.9726175***	
Vietnam		.89984254***	
Bolivia		-1.4504086***	
Brazil		2.9505553***	

Table D-9: Continued

Chile		1.1177482***	
Colombia		1.3874604***	
Costa Rica		1.0201554***	
Dominican Republic		-.14072139*	
Ecuador		-2.4744337***	
Guatemala		2.1127162***	
Jamaica		1.7514444***	
Mexico		-.63548499***	
Peru		1.9575607***	
Trinidad & Tobago		2.0053925***	
Uruguay		-.71471704***	
Venezuela		-.16810889**	
Bahrain		-.50386945***	
Iran		1.8893235***	
Iraq		1.2681576***	
Israel		3.5377557***	
Jordan		1.5101076***	
Oman		2.2557367***	
Qatar		-1.2030221***	
Saudi Arabia		1.8841533***	
Syrian Arab Republic		1.7087409***	
United Arab Emirates		1.1908446***	
Yemen		1.593946***	
Algeria		-1.1511344***	
Cameroon		-1.6702963***	
Côte d'Ivoire		1.6424662***	
DR Congo		1.5887887***	
Egypt		.755596***	
Ethiopia		-2.6311716***	
Ghana		.41545184***	
Kenya		2.3200367***	
Morocco		.4089296***	
Mozambique		.81725124***	
Nigeria		3.1799754***	
Senegal		1.9876057***	
South Africa		2.7041782***	
Sudan		.14448083*	
Tanzania		1.4899518***	
Tunusia		-.85074585***	
Zambia		-.5467968***	
Zimbabwe		-1.4906453***	
Argentina		-0,09927267	
_cons	1.0042668***	.2575768***	1.0042638***
N	2640	2640	2640
r2	0.00819805	0.9741117	
r2_a	-0.02641779	0.97320815	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-10: Pooled OLS, FE, and RE for cubic form of Model 3.1

Variable	pooled	fixed	random
DLGDP	-6.4089239*	-6.4089239*	-6.5485051*
DLGDP2	.70070892*	.70070892*	.71331125*
DLGDP3	-.0231628*	-.0231628*	-.02351314*
Belgium		.76390979***	
Cyprus		1.0474181***	
Denmark		2.5683914***	
Finland		1.8628154***	
France		2.9104147***	
Germany		-2.1108647***	
Greece		2.1742421***	
Iceland		-.19667187**	
Ireland		.27282494***	
Italy		1.7756332***	
Luxembourg		-1.0466697***	
Malta		2.5560943***	
Netherlands		.86871421***	
Norway		.74574659***	
Portugal		.16150966*	
Spain		-0,0972144	
Sweden		1.5728755***	
Switzerland		-1.355239***	
Turkey		-2.931239***	
United Kingdom		2.1148214***	
Canada		.19803689**	
United States		.28647403***	
Australia		.30552501***	
New Zealand		-3.3227222***	
Albania		2.1732333***	
Bulgaria		1.6663328***	
Hungary		2.1791578***	
Poland		-1.55942***	
Romania		1.7785572***	
Bangladesh		-.68139638***	
China		1.4753042***	
Hong Kong		1.6198193***	
India		2.0374335***	
Indonesia		-.39559411***	
Japan		-.19740683**	
Malaysia		1.2231672***	
Pakistan		1.1107597***	
Philippines		1.9921646***	
Singapore		1.8435871***	
South Korea		1.7428017***	
Sri Lanka		.94641894***	
Thailand		1.9758124***	
Vietnam		.90212475***	
Bolivia		-1.4469902***	

Table D-10: Continued

Brazil		2.9580928***	
Chile		1.116824***	
Colombia		1.3882289***	
Costa Rica		1.0226349***	
Dominican Republic		-.13895412*	
Ecuador		-2.4643246***	
Guatemala		2.1164967***	
Jamaica		1.7543608***	
Mexico		-.63211096***	
Peru		1.9624925***	
Trinidad & Tobago		2.0064068***	
Uruguay		-.71157097***	
Venezuela		-.16621995**	
Bahrain		-.50137053***	
Iran		1.8904801***	
Iraq		1.2698942***	
Israel		3.5249075***	
Jordan		1.5128002***	
Oman		2.2589372***	
Qatar		-1.1995317***	
Saudi Arabia		1.8885999***	
Syrian Arab Republic		1.7113113***	
United Arab Emirates		1.1891321***	
Yemen		1.5964867***	
Algeria		-1.150118***	
Cameroon		-1.6663428***	
Côte d'Ivoire		1.6461659***	
DR Congo		1.5927384***	
Egypt		.75759997***	
Ethiopia		-2.6260707***	
Ghana		.41372511***	
Kenya		2.3223206***	
Morocco		.408997***	
Mozambique		.81739006***	
Nigeria		3.1744323***	
Senegal		1.990847***	
South Africa		2.7084856***	
Sudan		.14548237*	
Tanzania		1.4932661***	
Tunusia		-.84680081***	
Zambia		-.54403909***	
Zimbabwe		-1.4874236***	
Argentina		-0.09922305	
_cons	1.0034139***	.25436699***	1.0033973***
N	2640	2640	2640
r2	0.00970407	0.97415101	
r2_a	-0.02526126	0.97323834	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-11: Pooled OLS, FE, and RE for quadratic form of Model 3.2

Variable	pooled	fixed	random
DLGDP	-1.1367148	-1.1367148	-1.1855339
DLGDP2	.08122042*	.08122042*	.08392314*
DLENUSE	.34815926***	.34815926***	.34902151***
Belgium		.74575527***	
Cyprus		1.0342071***	
Denmark		2.5562798***	
Finland		1.8493155***	
France		2.899222***	
Germany		-2.1306585***	
Greece		2.162075***	
Iceland		-.21262199***	
Ireland		.25874199***	
Italy		1.7703844***	
Luxembourg		-1.056204***	
Malta		2.5460745***	
Netherlands		.854958***	
Norway		.73275809***	
Portugal		.15316199*	
Spain		-0.11233792	
Sweden		1.5601406***	
Switzerland		-1.3720126***	
Turkey		-2.943007***	
United Kingdom		2.1052523***	
Canada		.19058625**	
United States		.27292748***	
Australia		.28725695***	
New Zealand		-3.3359665***	
Albania		2.1605398***	
Bulgaria		1.65421***	
Hungary		2.1702569***	
Poland		-1.5705142***	
Romania		1.7638337***	
Bangladesh		-.69563412***	
China		1.4662386***	
Hong Kong		1.6101818***	
India		2.0156835***	
Indonesia		-.41070732***	
Japan		-.21300569***	
Malaysia		1.2031031***	
Pakistan		1.0833509***	
Philippines		1.9823903***	
Singapore		1.8298763***	
South Korea		1.7299035***	
Sri Lanka		.9358308***	
Thailand		1.96262***	
Vietnam		.88601633***	
Bolivia		-1.45947***	

Table D-11: Continued

Brazil		2.9472576***	
Chile		1.1004073***	
Colombia		1.3742705***	
Costa Rica		1.0109172***	
Dominican Republic		-.15566335*	
Ecuador		-2.4768127***	
Guatemala		2.104909***	
Jamaica		1.7401451***	
Mexico		-.64290732***	
Peru		1.9468487***	
Trinidad & Tobago		1.9756814***	
Uruguay		-.72573769***	
Venezuela		-.17571331**	
Bahrain		-.51061078***	
Iran		1.8865314***	
Iraq		1.252757***	
Israel		3.5241415***	
Jordan		1.5080381***	
Oman		2.237467***	
Qatar		-1.2103605***	
Saudi Arabia		1.8667706***	
Syrian Arab Republic		1.6987208***	
United Arab Emirates		1.1709117***	
Yemen		1.58276***	
Algeria		-1.1606786***	
Cameroon		-1.6746731***	
Côte d'Ivoire		1.6345683***	
DR Congo		1.5806214***	
Egypt		.74013526***	
Ethiopia		-2.6387128***	
Ghana		.39640278***	
Kenya		2.2964212***	
Morocco		.39653785***	
Mozambique		.80321471***	
Nigeria		3.1675563***	
Senegal		1.9824774***	
South Africa		2.6987472***	
Sudan		.13433807*	
Tanzania		1.4799595***	
Tunusia		-.86469184***	
Zambia		-.56312868***	
Zimbabwe		-1.4969054***	
Argentina		-0.10548341	
_cons	1.0021666***	.26627536***	1.0021584***
N	2640	2640	2640
r2	0.0145887	0.97427851	
r2_a	-0.02020417	0.97337034	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

Table D-12: Pooled OLS, FE, and RE for quadratic form of Model 3.2

Variable	pooled	fixed	random
DLGDP	-5.4106002	-5.4106002	-5.5457531
DLGDP2	0.57332128	0.57332128	0.58543417
DLGDP3	-0.0184177	-0.0184177	-0.01875149
DLENUSE	.33423777***	.33423777***	.33500155***
Belgium		.74847852***	
Cyprus		1.0365178***	
Denmark		2.5597014***	
Finland		1.8526841***	
France		2.9020472***	
Germany		-2.125064***	
Greece		2.1652503***	
Iceland		-.21003459***	
Ireland		.26087323***	
Italy		1.7717194***	
Luxembourg		-1.0534118***	
Malta		2.5492873***	
Netherlands		.85531249***	
Norway		.73321975***	
Portugal		.15427444*	
Spain		-0.11082626	
Sweden		1.5612736***	
Switzerland		-1.3686367***	
Turkey		-2.942147***	
United Kingdom		2.1082476***	
Canada		.19069821**	
United States		.27529765***	
Australia		.28854172***	
New Zealand		-3.3302457***	
Albania		2.1634258***	
Bulgaria		1.6571515***	
Hungary		2.173199***	
Poland		-1.5677288***	
Romania		1.7663626***	
Bangladesh		-.69299073***	
China		1.4687605***	
Hong Kong		1.6123938***	
India		2.0194517***	
Indonesia		-.40770423***	
Japan		-.21167624***	
Malaysia		1.2047495***	
Pakistan		1.0899896***	
Philippines		1.9844062***	
Singapore		1.8323307***	
South Korea		1.7327592***	
Sri Lanka		.93823417***	
Thailand		1.9655601***	
Vietnam		.88838387***	

Table D-12: Continued

Bolivia		-1.4563896***	
Brazil		2.9533828***	
Chile		1.1003659***	
Colombia		1.375409***	
Costa Rica		1.0132582***	
Dominican Republic		-.15366065*	
Ecuador		-2.4686794***	
Guatemala		2.1082272***	
Jamaica		1.7429159***	
Mexico		-.6399277***	
Peru		1.9511985***	
Trinidad & Tobago		1.977676***	
Uruguay		-.72279545***	
Venezuela		-.17390726**	
Bahrain		-.50835422***	
Iran		1.8875627***	
Iraq		1.2547536***	
Israel		3.5144698***	
Jordan		1.5102619***	
Oman		2.2407424***	
Qatar		-1.2072917***	
Saudi Arabia		1.8710013***	
Syrian Arab Republic		1.7011654***	
United Arab Emirates		1.1703471***	
Yemen		1.5852275***	
Algeria		-1.1594888***	
Cameroon		-1.6713545***	
Côte d'Ivoire		1.6378259***	
DR Congo		1.5840885***	
Egypt		.74234691***	
Ethiopia		-2.6343554***	
Ghana		.39579148***	
Kenya		2.2991815***	
Morocco		.39708693***	
Mozambique		.80388636***	
Nigeria		3.1636454***	
Senegal		1.9852598***	
South Africa		2.7023894***	
Sudan		.13554*	
Tanzania		1.4829944***	
Tunusia		-.86099733***	
Zambia		-.56028286***	
Zimbabwe		-1.4940934***	
Argentina		-0.10519562	
_cons	1.0015724***	.26337529***	1.0015519***
N	2640	2640	2640
r2	0.01553066	0.9743031	
r2_a	-0.01962896	0.97338535	
	legend:	* p<0.05; ** p	<0.01; *** p<0.001

APPENDIX E

ALL ANALYSES IN DETAIL

Table E-1: FE Results for Model 1.1

Quadratic

Linear regression, absorbing indicators				Number of obs	=	780
				F(2,752)	=	85.41
				Prob > F	=	0.000
				R-squared	=	0.85
				Adj R-squared	=	0.891
				Root MSE	=	0.134
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-50.263	3.846	-13.07	0.000	-57.813	-42.714
D(lnGDP_pc)^2	2.447	.187	13.06	0.000	2.079	2.815
_cons	2.254	.006	374.01	0.000	2.243	2.267
COUNTRY	F(25,752)	= 209.87	Prob>F	=0.000		(26 categories)

Cubic

Linear regression, absorbing indicators				Number of obs	=	780
				F(3,751)	=	110.47
				Prob > F	=	0.000
				R-squared	=	0.911
				Adj R-squared	=	0.907
				Root MSE	=	0.124
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-545.515	43.411	-12.57	0.000	-630.736	-460.294
D(lnGDP_pc)^2	51.841	4.319	12.00	0.000	43.363	60.319
D(lnGDP_pc)^3	-1.638	.143	-11.45	0.000	-1.919	-1.357
_cons	2.252	.006	403.92	0.000	2.240	2.262
COUNTRY	F(25, 751)	= 250.96	Prob>F	=0.000		(26 categories)

Table E-2: Driscoll-Kraay SE Results for Model 1.1

Quadratic

Regression with Driscoll-Kraay standard errors					Number of obs =	780
Methods: Fixed-effects regression					Number of groups =	26
Group variable (i): COUNTRY					F(2,29) =	12.86
maximum lag: 3					Prob > F =	0.062
					Within R-squared =	0.185
$lnCO_2$_pc	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-50.263	9.912	-5.07	0.000	-70.536	-29.991
$D(lnGDP\_pc)^2$	2.447	.482	5.07	0.000	1.460	3.433
_cons	2.255	.018	127.28	0.000	2.219	2.291

Cubic

Regression with Driscoll-Kraay standard errors					Number of obs =	780
Methods: Fixed-effects regression					Number of groups =	26
Group variable (i): COUNTRY					F(3,29) =	88.19
maximum lag: 3					Prob > F =	0.000
					Within R-squared =	0.306
$lnCO_2$_pc	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-545.515	60.155	-9.07	0.000	-668.546	-422.485
$D(lnGDP\_pc)^2$	51.841	6.117	8.47	0.000	39.330	64.352
$D(lnGDP\_pc)^3$	-1.638	.207	-7.91	0.000	-2.062	-1.215
_cons	2.252	.017	136.18	0.000	2.218	2.285

Table E-3: F-Tests for Model 1.2

(Quadratic)	F (25, 751) = 315.15	Prob > F = 0.000
(Cubic)	F (25, 750) = 319.50	Prob > F = 0.000

Table E-4: Breusch-Pagan LM Test Results for Model 1.2

Quadratic

$lnCO_2\_pc$[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2\_pc$	.165	.406
e	.006	.078
u	.056	.237
Test: Var(u) = 0		
	chibar2(01) = 9086.19	
	Prob > chibar2 = 0.000	

Cubic

$lnCO_2\_pc$[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2\_pc$	1.622	1.274
e	.080	.283
u	1.188	1.090
Test: Var(u) = 0		
	chibar2(01) = 19211.54	
	Prob > chibar2 = 0.000	

Table E-5: Hausman Test Results for Model 1.2

Quadratic

Test: H_0: difference in coefficients not systematic	
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	0.72
Prob > chi2 =	0.868
(V_b-V_B is not positive)	

Cubic

Test: H_0: difference in coefficients not systematic	
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	3.03
Prob > chi2 =	0.387

Table E-6: Sargan-Hansen Test Results for Model 1.2

Quadratic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic	7.350	Chi-sq(3)	p-value =	0.062

Cubic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic	6.852	Chi-sq(4)	p-value =	0.144

Table E-7: RE Results for Model 1.2

Quadratic

Random-effects GLS regression				Number of obs =	780	
				Wald chi2(3) =	2002.88	
				Prob > chi2 =	0.000	
				R-squared =	0.730	
$lnCO_2\_pc$	Coef.	Std. Err.	z	P>IzI	[95% Conf. Interval]	
D(lnGDP_pc)	-4.027	2.543	-1.58	0.113	-9.012	.958
$D(lnGDP\_pc)^2$	.205	.124	1.66	0.097	-.037	.4478
lnENUSE	.750	.019	38.65	0.000	.712	.788
_cons	-3.979	.168	-23.70	0.000	-4.309	-3.650

Cubic

Random-effects GLS regression				Number of obs =	810	
				Wald chi2(4) =	2164.34	
				Prob > chi2 =	0.000	
				R-squared =	0.733	
$lnCO_2\_pc$	Coef.	Std. Err.	z	P>IzI	[95% Conf. Interval]	
D(lnGDP_pc)	-83.662	26.778	-3.12	0.002	-136.146	-31.179
$D(lnGDP\_pc)^2$	8.177	2.668	3.07	0.002	2.948	13.406
$D(lnGDP\_pc)^3$	-.265	.088	-3.00	0.003	-.439	-.092
lnENUSE	.740	.019	38.91	0.000	.703	.778
_cons	-3.890	.165	-23.64	0.000	-4.213	-3.568

Table E-8: Pesaran's & Friedman's Tests for Model 1.2

Quadratic

Pesaran's test of cross sectional indepence =	15.069,	Pr = 0.000
Friedman's test of cross sectional indepence =	121.342,	Pr = 0.000

Cubic

Pesaran's test of cross sectional indepence =	15.029,	Pr = 0.000
Friedman's test of cross sectional indepence =	116.694,	Pr = 0.000

Table E-9: Likehood Ratio Test for Homoskedasticity for Model 1.2

Quadratic

LR chi2(25) =	881.72
Prob < chi2 =	0.000

Cubic

LR chi2(25) =	881.06
Prob < chi2 =	0.000

Table E-10: Wooldridge test for autocorrelation for Model 1.2

Quadratic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,25) =	66.780
Prob > F =	0.000

Cubic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,26) =	73.141
Prob > F =	0.000

Table E-11: Robust Standard Errors for Model 1.2

Quadratic

Random-effects GLS regression					Number of obs =	780
					Wald chi2(3) =	375.11
					Prob > chi2 =	0.000
$lnCO_2$_pc	Coef.	Robust Std. Err.	z	P>IzI	[95% Conf. Interval]	
D(lnGDP_pc)	-4.027	4.049	-0.99	0.320	-11.962	3.908
D(lnGDP_pc)^2	.205	.195	1.05	0.029	-.177	.588
lnENUSE	.750	.062	12.19	0.000	.630	.871
_cons	-3.979	.482	-8.25	0.000	-4.925	-3.034

Cubic

Random-effects GLS regression					Number of obs =	780
					Wald chi2(4) =	786.06
					Prob > chi2 =	0.000
$lnCO_2$_pc	Coef.	Robust Std. Err.	z	P>IzI	[95% Conf. Interval]	
D(lnGDP_pc)	-104.432	56.915	-1.83	0.067	-215.982	7.119
D(lnGDP_pc)^2	10.133	5.536	1.83	0.067	-.717	20.984
D(lnGDP_pc)^3	-.327	.179	-1.82	0.069	-.678	.025
lnENUSE	.723	.070	10.30	0.000	.586	.861
_cons	-3.755	.559	-6.73	0.000	-4.849	-2.662

Table E-12: Hausman Test Results for Model 2.1

Quadratic

Test: H_0: difference in coefficients not systematic			
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)		
=	-0.49	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Cubic

Test: H_0: difference in coefficients not systematic			
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)		
=	-0.57	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Table E-13: FE Results for Model 2.1

Quadratic

Linear regression, absorbing indicators				Number of obs	=	1560
				F(2,1506)	=	8.37
				Prob > F	=	0.000
				R-squared	=	0.952
				Adj R-squared	=	0.950
				Root MSE	=	0.284
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-3.249	1.231	-2.64	0.008	-5.664	-.834
$D(lnGDP\_pc)^2$	.219	.074	2.98	0.003	.075	.364
_cons	.107	.008	14.24	0.000	.092	.122
COUNTRY	F(51, 1506)	= 565.69	Prob>F	=0.000		(52 categories)

Cubic

Linear regression, absorbing indicators				Number of obs	=	1560
				F(3,1505)	=	6.56
				Prob > F	=	0.000
				R-squared	=	0.952
				Adj R-squared	=	0.950
				Root MSE	=	0.131
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	8.104	6.766	1.20	0.231	-5.168	21.376
$D(lnGDP\_pc)^2$	1.295	.891	-1.45	0.146	-3.042	.452
$D(lnGDP\_pc)^3$	.066	.039	1.71	0.088	-.010	.142
_cons	.108	.008	14.35	0.000	.094	.123
COUNTRY	F(51,1505)	= 562.90	Prob>F	=0.000		(52 categories)

Table E-14: Driscoll-Kraay SE Results for Model 2.1

Quadratic

Regression with Driscoll-Kraay standard errors					Number of obs =	1560
Methods: Fixed-effects regression					Number of groups =	52
Group variable (i): COUNTRY					F(2,29) =	3.06
maximum lag: 3					Prob > F =	0.062
					Within R-squared =	0.011
$lnCO_2$_pc	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-3.249	1.391	-2.34	0.027	-6.093	-.405
D(lnGDP_pc)^2	.219	.090	2.43	0.022	.035	.404
_cons	.107	.041	2.54	0.015	.022	.192

Cubic

Regression with Driscoll-Kraay standard errors					Number of obs =	1560
Methods: Fixed-effects regression					Number of groups =	52
Group variable (i): COUNTRY					F(3,29) =	18.28
maximum lag: 3					Prob > F =	0.000
					Within R-squared =	0.223
$lnCO_2$_pc	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	8.104	5.057	1.60	0.120	-2.240	18.447
D(lnGDP_pc)^2	-1.295	.624	-2.08	0.047	-2.571	-.192
D(lnGDP_pc)^3	.066	.026	2.55	0.016	.013	.119
_cons	.108	.042	2.60	0.015	.023	.194

Table E-15: F-Tests for Model 2.2

F (51, 1505) = 566.54	Prob > F = 0.000
F (51, 1504) = 563.55	Prob > F = 0.000

Table E-16: Breusch-Pagan LM Test Results for Model 2.2

Quadratic

$lnCO_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2$_pc	1.622	1.274
e	.080	.284
u	1.195	1.093
Test: Var(u) = 0		
	chibar2(01) = 19332.41	
	Prob > chibar2 = 0.000	

Cubic

$lnCO_2$_pc[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2$_pc	1.622	1.274
e	.080	.283
u	1.188	1.090
Test: Var(u) = 0		
	chibar2(01) = 19211.54	
	Prob > chibar2 = 0.000	

Table E-17: Hausman Test without sigmamore command Results for Model 2.2

Quadratic

Test: H_0: difference in coefficients not systematic			
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)		
=	-0.46	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Cubic

Test: H_0: difference in coefficients not systematic			
chi2 (4) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)		
=	-0.58	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Table E-18: Hausman Test Results for Model 2.2

Quadratic

Test: H_0: difference in coefficients not systematic	
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	18.28
Prob > chi2 =	0.000

Cubic

Test: H_0: difference in coefficients not systematic	
chi2 (4) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	19.56
Prob > chi2 =	0.001

Table E-19: Sargan-Hansen Test Results for Model 2.2

Quadratic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	18.458	Chi-sq(3)	p-value =	0.000

Cubic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic:	19.755	Chi-sq(4)	p-value =	0.001

Table E-20: FE Results for Model 2.2

Quadratic

Linear regression, absorbing indicators					Number of obs =	1560
					F(3,1505) =	8.29
					Prob > F =	0.0000
					R-squared =	0.952
					Adj R-squared =	0.950
					Root MSE =	0.284
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf.	Interval]
D(lnGDP_pc)	-3.080	1.229	-2.51	0.012	-5.492	-.669
$D(lnGDP\_pc)^2$	.201	.074	2.73	0.006	.056	.345
D(lnENUSE_pc)	.391	.138	2.84	0.005	.121	.662
_cons	.105	.008	13.92	0.000	.090	.120
COUNTRY	F(51, 1505)	= 566.54	Prob>F	=0.000		(52 categories)

Cubic

Linear regression, absorbing indicators					Number of obs =	1560
					F(4,1504) =	7.02
					Prob > F =	0.0000
					R-squared =	0.952
					Adj R-squared =	0.951
					Root MSE =	0.131
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf.	Interval]
D(lnGDP_pc)	8.765	6.754	1.30	0.195	-4.482	22.012
$D(lnGDP\_pc)^2$	-1.379	.889	-1.55	0.121	-3.123	.364
$D(lnGDP\_pc)^3$	.069	.039	1.78	0.075	-.007	.144
D(lnENUSE_pc)	.398	.138	2.89	0.004	.127	.668
_cons	.106	.008	14.04	0.000	.091	.121
COUNTRY	F(51, 1504)	= 563.55	Prob>F	=0.000		(52 categories)

Table E-21: Pesaran CD Test for quadratic and cubic forms for Model 2.2

Quadratic

Pesaran's test of cross sectional independence = 33.619, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.560

Cubic

Pesaran's test of cross sectional independence = 32.460, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.561

Table E-22: Modified Wald Test for Homoskedasticity for Model 2.2

Quadratic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (52) = 47956.50
Prob > chi2 = 0.000

Cubic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (52) = 39078.23
Prob > chi2 = 0.000

Table E-23: Wooldridge test for autocorrelation for Model 2.2

Quadratic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,51) =	106.030
Prob > F =	0.000

Cubic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,51) =	106.251
Prob > F =	0.000

Table E-24: Driscoll-Kraay SE Results for Model 2.2

Quadratic

Regression with Driscoll-Kraay standard errors				Number of obs =		1560
Methods: Fixed-effects regression				Number of groups =		52
Group variable (i): COUNTRY				F(3,29) =		14.38
maximum lag: 3				Prob > F =		0.001
				Within R-squared =		0.014
$lnCO_2\_pc$	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-3.080	1.354	-2.27	0.031	-5.851	-.310
$D(lnGDP\_pc)^2$	.201	.087	2.31	0.028	.023	.379
D(lnENUSE_pc)	.391	.125	3.14	0.004	.137	.646
_cons	.105	.042	2.50	0.018	.019	.191

Cubic

Regression with Driscoll-Kraay standard errors				Number of obs =		1560
Methods: Fixed-effects regression				Number of groups =		52
Group variable (i): COUNTRY				F(4,29) =		6.54
maximum lag: 3				Prob > F =		0.000
				Within R-squared =		0.018
$lnCO_2\_pc$	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	8.765	4.970	1.76	0.088	-1.400	18.930
$D(lnGDP\_pc)^2$	-1.379	.608	-2.27	0.031	-2.623	-.136
$D(lnGDP\_pc)^3$	.069	.025	2.76	0.010	.018	.120
D(lnENUSE_pc)	.398	.128	3.11	0.004	.137	.659
_cons	.106	.042	2.53	0.017	.020	.192

Table E-25: FE Results for Model 3.1

Quadratic

Linear regression, absorbing indicators				Number of obs	=	2640
				F(2,2550)	=	10.54
				Prob > F	=	0.000
				R-squared	=	0.974
				Adj R-squared	=	0.973
				Root MSE	=	0.245
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-1.028	0.691	-1.49	0.137	-2.383	.326
$D(lnGDP\_pc)^2$	0.082	0.038	2.14	0.033	.007	.157
_cons	1.004	0.005	198.2	0.000	.994	1.014
COUNTRY	F(87,2550)	= 1062.48	Prob>F	=0.000		(88 categories)

Cubic

Linear regression, absorbing indicators				Number of obs	=	2640
				F(3,2549)	=	10.54
				Prob > F	=	0.000
				R-squared	=	0.974
				Adj R-squared	=	0.973
				Root MSE	=	0.245
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-6.409	2.819	-2.27	0.023	-11.936	-.882
$D(lnGDP\_pc)^2$	.701	.317	2.21	0.027	.080	1.322
$D(lnGDP\_pc)^3$	-.023	.012	-1.97	0.049	-.046	-.001
_cons	1.003	.005	197.42	0.000	.9934	1.013
COUNTRY	F(87,2550)	= 1062.48	Prob>F	=0.000		(88 categories)

Table E-26: Driscoll-Kraay SE Results for Model 3.1

Quadratic

Regression with Driscoll-Kraay standard errors				Number of obs =		2640
Methods: Fixed-effects regression				Number of groups =		88
Group variable (i): COUNTRY				F(2,29) =		10.95
maximum lag: 3				Prob > F =		0.000
				Within R-squared =		0.008
$lnCO_2\_pc$	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-1.028	0.661	-1.56	0.130	-2.379	0.322
$D(lnGDP\_pc)^2$	0.081	0.032	2.59	0.015	0.017	0.147
_cons	1.004	0.031	32.62	0.000	0.941	1.067

Cubic

Regression with Driscoll-Kraay standard errors				Number of obs =		2640
Methods: Fixed-effects regression				Number of groups =		88
Group variable (i): COUNTRY				F(3,29) =		6.95
maximum lag: 3				Prob > F =		0.001
				Within R-squared =		0.010
$lnCO_2\_pc$	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-6.409	3.908	-1.64	0.112	-14.402	1.584
$D(lnGDP\_pc)^2$	.701	.453	1.55	0.133	-0.227	1.628
$D(lnGDP\_pc)^3$	-.023	.017	-1.38	0.178	-0.057	0.011
_cons	1.003	.031	32.31	0.000	0.940	1.067

Table E-27: F-Tests for Model 3.2

F (87, 2549) = 1067.17	Prob > F = 0.000
F (87, 2548) = 1061.48	Prob > F = 0.000

Table E-28: Breusch-Pagan LM Test Results for Model 3.2

Quadratic

$lnCO_2\_pc$[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2\_pc$	2.247	1.499
e	0.060	0.245
u	1.757	1.326
Test: Var(u) = 0		
	chibar2(01) = 33954.36	
	Prob > chibar2 = 0.000	

Cubic

$lnCO_2\_pc$[Country, t] = Xb + u[Country] + e[Country, t]		
Estimated Results		
	Var	sd = sqrt(Var)
$lnCO_2\_pc$	2.247	1.499
e	0.060	0.245
u	1.487	1.219
Test: Var(u) = 0		
	chibar2(01) = 33539.66	
	Prob > chibar2 = 0.000	

Table E-29: Hausman Test without sigmamore command Results for Model 3.2

Quadratic

Test: H_0: difference in coefficients not systematic			
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)		
=	-0.63	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Cubic

Test: H_0: difference in coefficients not systematic			
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)		
=	-0.51	chi2<0 = =>	model fitted on these data fails to meet the asymptotic assumptions of the Hausman test

Table E-30: Hausman Test Results for Model 3.2

Quadratic

Test: H_0: difference in coefficients not systematic	
chi2 (3) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	24.85
Prob > chi2 =	0.000

Cubic

Test: H_0: difference in coefficients not systematic	
chi2 (2) =	(b-B)' [(V b-V_B) ^ (-1)] (b-B)
=	45.06
Prob > chi2 =	0.000

Table E-31: Sargan-Hansen Test Results for Model 3.2

Quadratic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic	25.054	Chi-sq(3)	p-value =	0.000

Cubic

Test of overidentifying restrictions: fixed vs random effects				
Cross-section time-series model: xtreg re				
Sargan-Hansen statistic	45.771	Chi-sq(4)	p-value =	0.000

Table E-32: FE Results for Model 3.2

Quadratic

Linear regression, absorbing indicators				Number of obs =		2640
				F(3,2549) =		12.58
				Prob > F =		0.000
				R-squared =		0.974
				Adj R-squared =		0.973
				Root MSE =		0.245
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-1.137	.689	-1.65	0.099	-2.488	.215
$D(lnGDP\_pc)^2$	.081	.038	2.13	0.034	.006	.156
D(lnENUSE_pc)	.348	.086	4.07	0.000	.180	.516
_cons	1.002	.005	197.35	0.000	.992	1.012
COUNTRY	F(87, 2549)	=1067.17	Prob>F	=0.000		(88 categories)

Cubic

Linear regression, absorbing indicators				Number of obs =		2640
				F(4,2548) =		10.05
				Prob > F =		0.0000
				R-squared =		0.974
				Adj R-squared =		0.973
				Root MSE =		0.245
$lnCO_2$_pc	Coef.	Std. Err.	t	P>ItI	[95% Conf. Interval]	
D(lnGDP_pc)	-5.411	2.823	-1.92	0.055	-10.945	.124
$D(lnGDP\_pc)^2$	.573	.317	1.81	0.071	-.049	1.196
$D(lnGDP\_pc)^3$	-.018	.012	-1.56	0.119	-.042	.005
D(lnENUSE_pc)	.334	.086	3.88	0.000	.165	.503
_cons	1.002	.005	196.74	0.000	.992	1.012
COUNTRY	F(87, 2548)	=1061.48	Prob>F	=0.000		(88 categories)

Table E-33: Pesaran CD Test for quadratic and cubic forms for Model 3.2

Quadratic

Pesaran's test of cross sectional independence = 37.752, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.552

Cubic

Pesaran's test of cross sectional independence = 37.931, Pr = 0.000
Average absolute value of the off-diagonal elements = 0.553

Table E-34: Modified Wald Test for Homoskedasticity for Model 3.2

Quadratic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (88) = 1.3e+05
Prob > chi2 = 0.000

Cubic

H_0: sigma (i)^2 = sigma^2 for all i
chi2 (88) = 1.3e+05
Prob > chi2 = 0.000

Table E-35: Wooldridge test for autocorrelation for Model 3.2

Quadratic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,87) =	167.802
Prob > F =	0.000

Cubic

Wooldridge test for autocorrelation in panel data	
H_0: no first-order autocorrelation	
F(1,87) =	167.890
Prob > F =	0.000

Table E-36: Driscoll-Kraay SE Results for Model 3.2

Quadratic

Regression with Driscoll-Kraay standard errors					Number of obs =	2640
Methods: Fixed-effects regression					Number of groups =	88
Group variable (i): COUNTRY					F(3,29) =	14.53
maximum lag: 3					Prob > F =	0.000
					Within R-squared =	0.015
$lnCO_2\_pc$	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-1.137	.614	-1.85	0.074	-2.393	.119
$D(lnGDP\_pc)^2$	.081	.029	2.78	0.009	0.021	.141
D(lnENUSE_pc)	.348	.086	4.06	0.000	0.173	.524
_cons	1.002	.031	31.85	0.000	0.938	1.067

Cubic

Regression with Driscoll-Kraay standard errors					Number of obs =	2640
Methods: Fixed-effects regression					Number of groups =	88
Group variable (i): COUNTRY					F(4,29) =	12.40
maximum lag: 3					Prob > F =	0.000
					Within R-squared =	0.016
$lnCO_2\_pc$	Coef.	Drisc/Kraay Std. Err.	t	P >ltl	[95% Conf. Interval]	
D(lnGDP_pc)	-5.410	3.750	-1.44	0.160	-13.079	2.258
$D(lnGDP\_pc)^2$	.573	.434	1.32	0.196	-.313	1.460
$D(lnGDP\_pc)^3$	-.018	.016	-1.15	0.260	-.0512	.0143
D(lnENUSE_pc)	.334	.081	4.15	0.000	.169	.499
_cons	1.001	.032	31.66	0.000	.937	1.066