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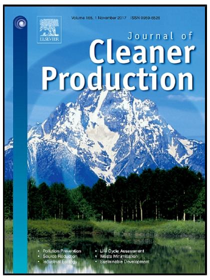

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Exploring the Relationship between Energy Usage Segregation and Environmental Degradation in N-11 Countries

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- We examine the EKC for CO_2 emissions in N-11 countries during 1990-2014
- We segregate three forms of energy consumption (renewable, biomass and non-renewable)
- Urbanization and trade openness are additional explanatory variables
- The empirical evidence confirms the presence of an N-shaped EKC

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1. Introduction

Energy consumption is an extremelycrucial factorfor enabling economic growth ofevery nation. Energy is consumed in various forms and one of the leading forms of global energy consumptionis fossil-fuel based energy. Nevertheless, over time, the continuous consumption of energy in the form of fossil fuels has resulted in two major predicamentsfor emerging economies:the rapid exhaustion of non-renewable natural resources and an increase in the emission of greenhouse gasses such as carbon dioxide (CO_2). Because of these mountingenvironmentalproblems, nations must develop clean technology and energy solutions, and in that pursuit, these nations must shift from non-renewable to renewable energy sources, including solar, wind, tidal, waste, and others forms. Nations around the world are progressivelyrecognizing the prospectsand implications of new sources of energy, and consequently, the share of renewable energy consumption in total energy consumption is increasing. By the end of 2015, more than 60nationsissued biofuel directives at a national or provincial level (REN21, 2016).

It is not hard to believe that the nexus between renewable energy consumption and environmental degradation may be a critical factor for sustainable development of emerging economies. Because the cross-border diffusion of technological progress is increasing, countries graduallyshift from less developed or developing stages to the emerging stage. This group of eleven countries is referred to as the“Next 11” or N-11 economies (Eghbal, 2008)[1]. According to the World Bank (2015), these countries represent approximately 8% of the global gross domestic product (GDP), which justifies the growth potential of these nations. In addition, the U.S. Energy

[1]These countries include Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Pakistan, the Philippines, Turkey, and Vietnam.

Information Administration reported that N-11 countries generate nearly 10% of the global CO_2 emissions (EIA, 2015), whichexplains the unsustainable nature of economic growth. A graphical representation of this growth has been provided in Figure-1. These countries are on a high economic growth trajectory, andconsequently, these nations' demand for energy isvery high, which raisesconcerns regarding environmental degradation without conciliating economic growth.

<Insert Figure 1 here>

During the past few decades, industrialization and population growth led to a rapid increase in global energy demand (Jegannathan and Nielsen, 2013; Lorek and Fuchs, 2013; UNFCC, 2015; UN, 2015). Currently, awareness of climate change and its repercussions arebeing widely discussedby the researchers(Meng et al., 2016; Wang et al., 2016b; Zeng et al., 2017 a, b).Inthe early 1990s,ambient pollution problems began to be more frequently described in studies regarding energy economics (Grossman and Krueger, 1991).Stern (2007) described this phenomenon and reported that environmental degradation processes could generate a global economic recession. This trend has also been observed in recent years in developing countries.Therefore, determiningenergyconsumption patternsthat occur during the course of economic growth is one of the most essentialmethodsto achievesustainable development.

Numerous theoretical frameworks have been used to consider the effect of economic growth patterns on environmental degradation,and the Environmental Kuznets curve (EKC) hypothesis is one of the most frequently used frameworks. Thetheoretical framework of the EKC hypothesis establishes the existence of a relationship between economic growth and environmental quality. In addition, this model allows the incorporation of additional explanatory variables, which help clarify the evolution of environmental degradation process. In this study,we use the EKC frameworkand incorporate a set of explanatory variables to explore the impact of economic growth on CO_2 emissions for N-11 economiesduring 1990-2014. This study explores the impact of income, renewable energy consumption, biomass energy consumption, non-renewable energy consumption, trade openness, and urbanization on CO_2 emissions.Prior studies have investigatedthe (a) impacts of renewable energy sources on CO_2 emissions and (b) differential impacts of renewable and non-renewable energy sources on CO_2 emissions.Bilgili et al. (2016) analyze the impact of renewable energy consumption on CO_2 emissions for 17 OECD countries during 1977-2010 and determinethat renewable energy consumption has a negative impact on CO_2 emissions. Dogan and Seker (2016a) examine the association between CO_2 emissions, renewable and nonrenewable energy, real income and trade openness for European Union nations during 1980-2012. Their empirical results demonstrate that renewable energy consumption has a negative impact on CO_2 emissions.Álvarez-Herranz et al. (2017a)probe the impact of energy innovation and renewable energy consumption on CO_2 emissions for 17 OECD countries during 1990-2012. They find that renewable energy consumption has a negative impact on CO_2 emissions. Riti et al. (2017) investigated the association between CO_2 emissions, fossil fuel energy consumption, and real income for China during 1970-2015.Their empirical results demonstrate that energy consumption has a positive impact on CO_2 emissions.

The results from prior studiesindicate that certain research gaps exist. For example, we have not found a study that has considered the impact of biomass energy consumption on CO_2 emissions. Prior studies generally segregate renewable and non-renewable energy sources; further segregation of the components of renewable energy consumption has largely been ignored. Trade volume and energy consumption patternsare highly linked with economic growth, and therefore, the interactions between these variables may impact CO_2 emissions. This study contributes to existing literature regarding energy economics in five ways.(i) This study uses the EKC framework to investigate the associationsamong income, renewable energy consumption, biomass energy consumption, non-renewable energy consumption, trade openness, urbanization, and CO_2 emissions for a panel of N-11 countries.(ii) We applied the generalized method of moments (GMM) to estimate the relationship between these variables.(iii) Our research introducesinteraction effects between trade openness and biomass energy consumption with income, and these interaction variables have a dampening effect on CO_2 emissions in N-11 countries.(iv)Wesegregated the use of renewable energy and biomass energy consumptions to determine the possible impact of these energy sources on CO_2 emissions. (v) We also consider three subpanels that are constructed based onWorld Bank (2016) classifications(developed, industrialized, and emerging countries). Our results demonstrate that an N-shaped environmental Kuznets curve exists for N-11 countries and for the three subpanels.

The remainder of this paper is organizedas follows: Section-2 provides a review of relevant literature, Section-3 provides the theoretical framework of the EKC hypothesis, Section-4 summarizes the present energy policies of N-11 countries, Section-5 describes the empirical model and data, Section-6 details the results and analysis, and Section-7 concludes the paper with policy implications.

2. Literature review

Over the past few decades, numerous studies have explored the link between economic growth, energy consumption, and CO_2 emissions (Ozcan, 2013;Dogan and Seker, 2016a,Menget al., 2016, Zenget al., 2017a, b,among others). Our study hypothesizes the existence of a relationship between economic growth and environmental degradation in N-11 emerging economies. Below, wereview prior studies regarding thegrowth-emissions nexus, the trade-emissions nexus and the urbanization-emissions nexus.Then, wediscuss these relationships in the subsequent subsections.

2.1.Economic Growth and CO_2 Emissions

Thereis an extensive volume of literature regarding Energy and Environmental Economics and the association between economic growth and CO_2 emissions. During the earliest stage of economic growth, nations primarily depend on fossil fuels for fulfilling their energy demands.Burning those fossil fuelssubsequentlygenerates CO_2 emissions in the ambient atmosphere; an increase in the consumption of fossil fuels gradually increases the level of CO_2 emissions. Therefore, to a degree, patterns of economic growth exertnegative pressures on environmental quality. Once economic growth reaches a certain level, increasing levels of pollution and environmental awareness among citizens force policymakers and industries to shift towards cleaner technologies and green energy resources, and economic growth pattern leads to a reduction in atmospheric CO_2 emissions. This implies that the relationship betweenCO_2 emissionsand economic growth isan inverted U-shaped, and this entire phenomenon is referred as the Environmental Kuznets curve (EKC) hypothesis.

Grossman and Krueger (1991) proposedthe famous EKC hypothesisby assessing the impact of the North American Free Trade Agreement (NAFTA) on environmental quality of Mexico City. These scholars discovered a new dimension in evaluating the emissions levels in thecontext of economic growth.Over the years, researchers have estimated the EKCs for a wide range of pollutantsand various forms of the EKC have been discovered, e.g.,inverted U-shaped, U-shaped, N-shaped, inverted N-shaped, M-shaped, and linear.

The situation may be similarinthe case of CO_2 emissions. One of the earliest studies regarding EKCframework estimation for CO_2 emissions was conducted by Shafik and Bandyopadhyay (1992). These scholars analyzed 149 countries during 1960-1990 and could not determine EKC hypothesis.A for a single-country context, the seminal study was conducted by Carson et al. (1997). They analyze 50 states in the US during 1988-1994 and discover an inverted U-shaped EKC pattern, with the turnaround point at $62,700 per capita.Following the path of these studies, over the last three decades,researchers have attempted to estimate EKCs for CO_2 emissions for various nations, and recently with a special focus on emerging countries. Abdou and Atya (2013) investigate the EKC of Egypt during 1961-2008 and find the evidence of an inverted U-shaped EKC. Within the EKC framework, Rabbi et al. (2015) analyze the association between per capita CO_2 emissions, energy use, per capita real GDP, and trade openness for Bangladesh during 1972-2012. Using a cointegration model, theynote the evidence of an inverted U-shaped EKC.Saboori et al. (2012) conductthe first EKC estimation study of Indonesia and analyze the associationsamong CO_2 emissions, economic growth, energy consumption, and foreign trade during 1971-2007. In alignment with the Auto-Regressive Distributed Lag (ARDL) approach, theydetermine that an EKC does not exist for Indonesia. Sugiawan and Managi (2016)estimatethe EKC for Indonesia during 1971-2010 but present contradictory empirical evidences. Few EKC estimation studies have been conducted in the Korean context, and one of the earliest studies is conducted by Kim and Jung (2014). They analyze the impact of GDP on CO_2 emissions for 15 local government regions in Korea during 1990-2010. Using a panel Generalized Least Square (GLS) model, theyfind the evidence of an inverted U-shaped EKC. Most of the studies conducted in Mexico largely focus on pollutants other than CO_2, and Gallagher's (2005) study is one of only a few studies that did focus on

CO_2emissions. Gallagherfocused on the impact of economic integration on CO_2 emissions in Mexico during 1985-2000 and found evidence of several turnaround points of an inverted U-shaped EKC at various levels of economic integration. Bello and Abimbola (2010) estimate the EKC for CO_2 emissions in Nigeria during 1980-2008. In alignment with the GMM approach, theyare unable tofind evidence of an EKC in Nigeria. In a subsequent study by Chuku (2011),the EKC is tested during 1960-2008, and the turnaround points of inverted U-shaped EKCs arefound in the range of \$237.23-\$280.84 per capita.One of the earliest and comprehensive EKC estimation studies for Pakistan was conductedby Shahbaz et al. (2011). This study has analyzed the relationship between CO_2 emissions, energy consumption, economic growth, and trade openness during 1971-2009 and by applying thebounds test for the cointegration approach.Theyfind the evidence of an inverted U-shaped EKC[2]. Seriño (2014) conducts the only EKC estimation study for the Philippines and attempted to estimate the impact of household consumption on CO_2 emissions during 2005-2006. The results demonstratethat an inverted U-shaped EKC exists for the Philippines.Halicioglu (2009) estimates the EKC for Turkey and analyzed CO_2 emissions, energy consumption, income, and foreign trade during 1960-2005.Using the ARDL and ECM approaches, Haliciogludetermines that an inverted U-shaped EKC exists for Turkey[3]. Finally, Tang and Tan (2015) conduct an EKC estimation study for Vietnam to analyze the association between CO_2 emissions, energy consumption, income, and foreign trade during 1976-2009. Using the cointegration approach, they find evidence of an inverted U-shaped EKC in Vietnam. However, in a subsequent study that has conducted by Al-Mulali et al. (2015a), the results did not provide evidence to support the EKC hypothesis.

[2] Similar results were obtained in subsequent studies that were conducted by Shahbaz et al. (2012) and Shahbaz (2013); these studies also provided evidence of inverted U-shaped EKCs in Pakistan.
[3]Shahbaz et al. (2013b) estimated the EKC for Turkey during 1970-2010 and analyzed CO_2 emissions, energy intensity, economic growth, and globalization. Using the ARDL and ECM approaches, the researchers found evidence of an inverted U-shaped EKC in Turkey.

A recent studythat has conducted by Shahbaz et al. (2016b)to estimate the EKC for CO_2 emissions in N-11 countries by considering CO_2 emissions, energy consumption, and economic growth within the EKC framework. They find the evidence of an inverted U-shaped EKC for all N-11 countries. All of these studies, including the single country and cross-country analyses, are inconclusive in terms of suggesting the shape of the EKC for N-11 countries. Furthermore, none of these studies segregated the effects of renewable and non-renewable energy consumptions and analyzed their effects on CO_2 emissions. This is one of the primary contributions of this study to extant literature. In addition,prior studies estimated the EKCs by using the square of income, but this study considers the cubed-term of income and thusprovides a scope for the N-shaped EKC of N-11 countries.

2.2. Trade Openness and CO_2 Emissions

Trade openness may impact CO_2 emissions via various channels, and the impact can either be positive or negative. For an industrialized or developed nation, trade openness results in a technique effect on the economy by introducing technologies that pollute less duringproduction processes. Therefore,the production processesbecome more environmentally sustainable by decreasing ambient pollution levels. Conversely, if the economy is in a nascent phase of development, to boost growth, policymakers of developing nations insist on procuring low cost and polluting technologies from developed nations. In this scenario, economic growth via technology, tradeoccurs at the cost of environment. Therefore, in this case, trade causes production process to become environmentally unsustainable by increasing ambient pollution levels.

Numerous studies that explore the EKC relationship incorporate trade openness as a significant variable (Grossman and Krueger,1991;Wyckoff and Roop, 1994; Suri and Chapman,1998;Nahman and Antrobus,2005;Feridun et al., 2006;Halicioglu, 2009;Baek and Kim, 2011;Jayanthakumaran et al., 2012). These studies conclude that increases in trade result in higher global environmental pollution levels. Conversely, this intuition has been invalidated empirically for local pollutants (such as SO_2 and NO_2); however, the relationship is mostly positivefor global pollutants such as CO_2 emissions (Frankel and Rose, 2005).Feridun et al. (2006) demonstratethat pollution is positively related to trade openness in Nigeriaduring 1980-2000. Halicioglu (2009) examines the relationship between CO_2 emissions, energy consumption, income and foreign trade for Turkey during 1960-2005 and concludes that increases in trade inflowsresulted inincreases in CO_2 emissions. Furthermore,Baek and Kim (2011) determinethat trade openness and income growth positively and significantly affect environmental quality for developed countries, but environmental degradation increased because of trade openness and economic growth in developing countries. In addition, theynotethat an adverse relationship existed between energy consumption and environmental quality. Conversely, Jayanthakumaran et al. (2012) determined that trade openness has a similar impact on CO_2 emissions in China and India. Shahbaz et al. (2014) analyze the association between electricity consumption, industrial value-added activities, domestic credits to the private sector, trade openness, and CO_2 emissions for Bangladesh during 1975-2010 and determinethat trade openness leads to an increase in CO_2 emissions.

Certain studies have broadened the analysis of the association between trade openness and CO_2 emissions by considering multivariate frameworksand includingfinancial development, HDI, and institutional quality (e.g., Ibrahim and Law, 2015; Shahbaz et al., 2015;Al-Mulali et al., 2016; Sinha and Sen, 2016, and many others). The results of these studies have been inconclusive regarding the impact of trade openness on CO_2 emissions.These studies describe the impact as both positive and negative depending on the context, choice of other explanatory variables, and methodological adaptations.

2.3. Urbanization and CO_2 emissions

Urbanization plays a significant role in influencing environmental quality via various channels. When industrialization sets a pace in an economy, newly built factories and plants must hire employees. Because these companies require several operational and logistical facilities, factories are built near the cities,and occasionally, several small towns are formed around these production units. Toincrease their income and pursue a better lifestyle, individuals move away from villages and rural areasand seek employment opportunities at these production units. Because of this process,population in urban areas increases.The migrated populace adds to population of the cities and towns, anddemand for energy increases within a short span of time. Fossil fuel consumption increases to meet this elevated demand for energy, which subsequently increases CO_2 emissions levels in the troposhperic atmosphere. In addition to this particular channel, urbanization can cause environmental degradation in several other ways.Numerous researchers have determined that the degree of transportation, vehicular congestion, energy waste, and space heating are possible consequences of urbanization (Sinha, 2015;Sinha and Bhattacharya, 2016, 2017).Therefore, it is imperative to consider urbanization in the empirical framework when analyzing the carbon emissions in developing nations.

Cole and Neumayer (2004) conduct one of the earliest studies considering urbanization within the EKC framework. They analyze the relationship between CO_2 emissions, growth in manufacturing industries, age structure of the population, per capita GDP, energy intensity, and urbanization for 86 countries during 1975-1998. Their study applied a panel regression model and determined that urbanization leads to an increase in CO_2 emissions. Martínez-Zarzoso and Maruotti (2011) investigate the relationship between per capita income, population, urbanization, energy efficiency and industrial activityon CO_2 emissions andconclude that urbanization leads to an increase in CO_2 emissions, irrespective of the stage of development of the 88 countries.Wang et al. (2012) analyze the association between urbanization, GDP, industrial growth, tertiary industry proportion, energy intensity, R&D output, and CO_2 emissions for Beijing during 1997-2010. Usingthe partial least square approach, they determine that urbanization is the primary driver for an increase in emissions. Chen and Huang (2013)examine the association between energy use, electric consumption, FDI, GDP, urban population, and CO_2 emissions for N-11 countries during 1981-2009using the panel cointegration and causality approach. They find that urbanization increases electric power consumption and carbon emission.

Hassan and Salim (2015), Shahbaz et al. (2015), Al-Mulali et al. (2016), Ali et al. (2016), Destek et al. (2016), Kang et al. (2016), Wang et al.(2016a, b), He et al. (2017) and several other studiesextend the urbanization-emissions nexus to include diverse aspects.Theyhave used multivariate frameworks to considerdimensions such asspatial dispersion, dynamics of nations, income inequality, and land use patterns,but the results were inconclusive.

3. Theoretical framework of EKC analysis

According to the EKC hypothesis, during the early stages of economic development, increase in income will increase pollution until it reaches to a certain point because this relationship is an inverted-U scheme, and then relationship between income and pollution becomes negative.It implies that theEKC hypothesis theoretically demonstrates a country's transition from developing to developedvia economic growth(Grossman and Krueger, 1991). To clarify, the relationship between economic growth and environmental quality implies that environmental degradation is an increasing function of economic activity to apoint;beyondthis point, higher income levels lead to improve environmental quality (Grossman and Krueger, 1991, 1995;Halkos, 2003;Balsalobre and Alvarez, 2016). This argument can be analyzed by consideringthree channels through which economic growth affects the environment: scale effect, composition effect, and technique effect (Figure-2).

<Insert Figure 2 here>

Figure-2 illustrates howthe scale effect is associated with the sectoral structure of an economic system.During thepre-industrial stage,limited consumption of natural resources and a restricted production of biodegradable wasteskeep the level of environmental degradation low. As the speed of economic growth increases because of agriculture, the use of forest resources and the extraction of natural resources begin to surpass regeneration rates.A gradual increase in industrializationincreases the quantity and toxicity of non-degradable waste. During the developing stage of economic development, an increase in income levels will not only increase outputbut will also deteriorate environmental quality. The scale effect implies that the margin of new improvements generates increasing returns in terms of reducing pollution (Torras and Boyce, 1998). Over time, economic development generates a growth in knowledge intensive industries and a refinement of production processes; these two scenarios describe the composition and technique effects, respectively (Figure-2). The composition effect exerts a positive impact onenvironment when an economytransitionsfrom an agriculture and heavy manufacturing sectorto acknowledge intensive sector. The sectoral transition that is caused by the composition effect reducesintensive energy consumption and toxic emissions, thereby decreasing emissions and reversing the slope of the EKC (Hettige et al., 2000;Halkos, 2003). Finally, the technical effect catalyzesimprovements in productivity and the adaptation of cleaner technologies, which leads to an increase in environmental quality. Andreoni and Levinson (2001) concluded that economic growthcorrects environmental contamination levelsvia technical factors andreduces the slope of the EKC to a greater extent. In addition, the emergence of knowledgeintensive industries and growing environmental concernsmay lead to more stringent environmental regulations, the introduction of cleaner technologies, the replacement of obsolete and polluting technologies, and additional environmental investments. This period is followed by a stabilization and gradual decrease in environmental degradation.Technical innovation is the primary driver of this process (Andreoni and Levinson, 2001). Therefore, it can be inferred that when technical innovation reinforces the endogenous aspect of the EKC hypothesis (Gradus and Smulders, 1993;van den Bergh and Nijkamp, 1994), the technicaleffect conditions the income-emissions associationviaimprovingenergy technologies, replacing obsolete and polluting technologies with cleaner technologies and introducingmore efficient production processes (Verdier, 1993;Bovenberg and Smulders, 1995).

In addition, an N-shaped EKC pattern describes the relationship between income per capita and the level of environmental pollution in accordance with the EKC (Figure-3). Although pollution decreases with an increase in income levels, after the scale effect exceeds the technical effectand technical obsolescenceoccurs, the level of ambient pollution begins growing again (Balsalobre and Álvarez, 2016;Álvarez et al., 2017a, b).

<Insert Figure 3 here>

During the first stage of economic growth, economies remain in a developing stage that is characterized by policies that create distortions, subsidize energy consumption, and result in market failures (De Bruynet al., 1998). During the second stage, distortions disappear and market failures arecorrected. During the subsequent development stage, strict environmental policies are applied, and environmental awareness increases. Institutional changes during this stage explain the behavioral patterns that are described by the EKC hypothesis (Jones and Manuelli, 1995). Finally,the relationship between income and environmental pollutionis N-shaped; when technical advances no longer have increasing returns, a second stage occurs and decreasing technical returns force economies to return to a state of increasing environmental destruction (Balslaobre and Álvarez, 2016).

4.Empirical modeland data

This study tests the validity of the EKC hypothesis on the relationship between economic growth and carbon emissions based on the following three simultaneous equations:

$$Y_{it} = a_0 + a_1R_{it} + a_2B_{it} + a_3N_{it} + a_4L_{it} + a_5H_{it} + a_6T_{it} + a_7W_{it} + a_8K_{it} + \varepsilon_{it} \quad (1)$$

$$C_{it} = b_0 + b_1Y_{it} + b_2\,Y_{it}^2 + b_3\,Y_{it}^3 + b_4\,R_{it} + b_5\,B_{it} + b_6\,N_{it} + b_7\,T_{it} + b_8\,B_{it}{*}Y_{it} + b_9\,U_{it} + \varepsilon_{it} \quad (2)$$

$$C_{it} = c_0 + c_1Y_{it} + c_2Y_{it}^2 + c_3Y_{it}^3 + c_4R_{it} + c_5B_{it} + c_6N_{it} + c_7T_{it} + c_8T_{it}{*}Y_{it} + c_9U_{it} + \varepsilon_{it} \quad (3)$$

In these equations, i =1…N denotes the sample countries, t =1…T refers to the study period, and ε represents the error term. Eq. (1) is an extended form of the Cobb-Douglas production function. In this model, per capita GDP is presented in current US dollars (Y) and is dependent on per capita renewable energy consumption (R),[4] per capita biomass energy consumption (B), per capita fossil fuel energy consumption (N), labor force (L), a human development indicator (H), trade openness (T), per capita combustible renewable energy waste (W), and per capita gross

[4]Renewable energy consumption data does not include biomass energy consumption.

capital formation (*K*). Eq. (2) demonstrates that per capita CO_2 emissions (*C*) can be influenced by per capita GDP (*Y*), squared per capita GDP (Y^2), cubed per capita GDP (Y^3), per capita renewable energy consumption (*R*), per capita biomass energy consumption (*B*), per capita fossil fuel energy consumption (*N*), trade openness (*T*), urbanization (*U*), and the interaction between per capita biomass energy consumption and per capita GDP (*B**Y*). Eq. (3) is similar to Eq. (2) with the exception of the interaction factor; in Eq. (3), per capita CO_2 emissions (*C*) is hypothesized to be influenced by the interaction between trade openness and per capita GDP (*T**Y*).

In this model, we estimated the association between CO_2 emissions, economic growth, energy consumption (renewable biomass and non-renewable), energy efficiency, trade openness,HDI, labor force, and the rate of urbanization.It is evident from Eq. (2) and Eq. (3) that our study focuses on investigating whether the association between economic growth and carbon emissions is either anN-shaped or inverted N-shaped EKC (see Shafik and Bandyopadhyay, 1992;Grossman and Krueger, 1995;Torras and Boyce, 1998;Balsalobre et al., 2015;Sinha and Bhattacharya, 2016, 2017;Álvarez-Herranz et al., 2017 a, b,and others)[5]. The N-shaped pattern allows us to focus on issues that are related to scale effect and the long-term effects of energy efficiency. This characteristicallows us to analyze the potential return to increasing emissions once economies have managed to reduce pollution rates and an environmental technical obsolescence may occur.Conversely, the inverted N-shaped pattern demonstrates that it is not essentialfor a nation to have a low level of environmentaldegradationonce it has fallen to a

[5]The EKC demonstrates a repeated phenomenon that results in a positive association between economic activity and pollution levels up to a certain level of critical income; a higher level of income is associated with progressively greater levels of environmental qualityfollowed by a U-inverted pattern (Grossman and Krueger, 1991). In the short term, environmental degradation increases with economic growth but when a certain level of income is reached, continued increases are associated with improved environmental quality. Meanwhile, certain studies (Shafik and Bandyopadhyay, 1992;Grossman and Krueger, 1995) provide evidence ofa N-shaped pattern for theEKC. Meanwhile, Moomaw and Unruh (1997) suggest that an N-shaped EKC in developed countries is justified by the structural transition from developing to the developed stage.

certain level. It may be possible that because of changes in socio-economic scenario, environmental degradation may begin increasing for a second time. However, during advanced stages of economic growth, technical effect can reduce the level of environmental degradation.

In Figure-4, the turning point of an N-shaped EKC is illustrated. We compare this with the models that are represented by Eq. (2) and Eq. (3). The coefficients b_1, $c_1 > 0$, b_2, $c_2 < 0$, and b_3, $c_3 > 0$ indicate a cubic polynomial in an N-shaped EKC. The coefficients b_1, b_2, b_3, c_1, c_2, and c_3 also allow us to calculate the turning points in the cubic EKC model: X(1) and X(2).[6]

This study employed annual data for the period of 1990-2014 to examine an N-shaped linkage between economic growth and environmental degradation for N-11 countries andincluded additional determinants of carbon emissions. In addition, this study uses the EKC frameworkand includes the interaction between economic growth and biomass energy and between economic growth and trade openness to explore the moderation. Economic growth is expected to transition economic systems from the developing stage to the developed stage, and during this process carbon emissions might be reduced. The impact on biomass energy is expected to be similar to the impact on CO_2 emissions.

<Insert Figure 4 here>

Equations (1), (2), and (3) weresimultaneously estimated using the generalized method of moments (GMM). GMManalyzes the linkages between variables within a panel data setting andprovides reliable results. During this analytical process, there are possibilities of endogenous

[6]The estimation of the turning points for the cubic model used the following formulation (Diao et al., 2009):

$$X(j) = \frac{-b_2 \pm \sqrt{b_2^2 - 3b_1 b_3}}{3b_3}, \forall j = 1,2$$

For estimating the turning points, it is necessary to make a change in the coefficient b_1, since the breaking point where the function reaches the maximum and minimum values depends on X. When X appears in the moderate model GDPpc, this will affect the coefficient of the first grade. Therefore, the coefficient $b_1 = (b_1 + b_3 * X)$ and X assumes its median value, which is justified by the asymmetric distribution of that variable.

and heteroscedasticissues, which can be addressed by the instrumental variables that are used within a GMM framework (Arellano and Bover, 1995; Blundell and Bond, 1998;Halkos et al., 2003). The Hansen-J test has been used to examine over-identification issues and to determine the validity of the instruments that are used within the framework[7]. The Durbin-Wu-Hausman test is used to check for possible endogeneity in the model[8].

The data used in this study are for N-11 countries during 1990–2014. We collected the annual data for per capita CO_2 emissions (in kt), per capita GDP (constant 2010 US$), per capita Renewable Energy Consumption (in kt), per capita Fossil Fuel Energy Consumption (in kt), Labor Force, Trade Openness (as a % of GDP), per capita gross capital formation (constant 2010 US$), per capita combustible renewable and waste (in kt), and urbanization from World Bank Indicators, per capita biomass energy consumption (in t) from the Global Material Flows Database of Vienna University, and the Human Development Indicator from the Human Development database of United Nations Development Programme.

To add more information to the analysis, the dataset of N-11 countries was segregated into three categories, which include the developed category (South Korea), the newly industrialized category (Indonesia, Mexico, Iran, Philippines, and Turkey), and the emerging category (Bangladesh, Egypt, Nigeria, Pakistan, and Vietnam). This classification has been provided by the World Bank (2016). The empirical model is shown in Figure-5.

5. Empirical Results and Discussion

[7]The null hypothesis of this test indicates that the instruments are valid, and therefore, the results of this test should be insignificant to ensure that the null hypothesis can be accepted.
[8]The null hypothesis of this test indicates that the model is exogenous, and therefore, results of this test should be significant to ensure that the null hypothesis can be rejected.

We began the process by testing the unit root properties of the variables because it is important to know the order of integration of the variables. To checkthe order of integration, we applied unit root tests, including theLevin-Lin-Chu (LLC) test (Levin et al. 2002), Breitung (2002), Im-Pesaran-Shin (Im et al. 2003) and the Fisher-type augmented Dickey-Fuller test (Maddala and Wu, 1999). The applicability of these tests was confirmed by the results of the cross-section dependence test (Pesaran, 2007),and the results are provided in Table-1. Clearly, the cross sections are independent up to 4 lags, and this provides evidence regarding the applicability of the first-generation unit root tests. The results of the unit root tests are provided in Table-2 and indicate that the variables do not demonstrate the presence of unit root problemsafter their first differences. Therefore, it can be concluded that the variables are integrated to order one, i.e., I(1).

<Insert Table 1 here>

<Insert Table 2 here>

<Insert Table 3 here>

<Insert Table 4 here>

<Insert Table 5 here>

<Insert Figure5 here>

The results that are estimated by GMM for Eq. 1 areprovided in Table-5 and demonstrate that, as a whole,renewable energy consumption has a positive impact on economic growth for developed and industrialized countries and a negative impact on emerging countries and N-11 countries.This scenario can be explained in terms of the cost aspects of renewable energy generation. If the individual countries of the N-11 panel are considered, then the countries in the developed and industrialized categories can afford the cost of renewable energy implementation without dampening economic growth. Conversely, the immediate impact of renewable energy consumptionis noted in the case of the emerging countries because they undertook this initiative at a later stage. Therefore, the impact of this initiative is negative on their economic growth pattern. The overall impact of renewable energy consumptionis negative on economic growth of N-11 countries.In contrast, the impact of non-renewable fossil fuel consumption is positive on the economic growth pattern for all panels. The results indicate that non-renewable fossil fuel consumptioncontinues to be the major player in the energy mix and economic growth is driven by energy sources. Therefore, it is not surprising that thisimpact is positive.Various prior studies noted that non-renewable energy consumption has a positive impact on economic growth and this segment of our result alignswith these studies (for more details, see Ozturk, 2010).

One of the significant findingsof this study concerns the impact of biomass energy consumption on economic growth. Because the percentage of this particular form of energy is gradually increasing in the energy mix,the cost of this energy is comparatively lower when compared to renewable energy.Therefore, biomass energy consumption is significantly contributing to economic growth.This result is similar toBildirici (2013). However, a lack of energy efficiency harms economic growth; this is demonstrated by the negative coefficient of renewable energy waste.Although the impact is not significant for the developed and emerging categories, the impact is negative and significant for industrialized economies and N-11 countries as a whole. This result aligns with Sinha (2015). The waste of renewable energy demonstrates a lack of energy efficiency, and it is this wasted amount of energy that does not contribute to economic growth. This waste generally includes solid biomass, liquid biomass, and biogas. Because this lack of energy efficiency,asmeasured by renewable energy waste,negatively impacts economic growth, policy level interventionsare required to enhance energy efficiency by reducing energy waste.

These nations are still largely dependent on non-renewable fossil fuel consumption, and these energy consumption patternssubsequently deteriorate environmental quality by creating ambient air pollution, of which the majority is tropospheric CO_2 emissions. These CO_2 emissionsgraduallycreate respiratory problems for the labor forcethatsubsequently deteriorate their hygienic state;consequently, economic growth is adversely affected. The negative impact of CO_2 emissions on economic growth bears this evidence. This aspecthas been supported by numerous prior studies(e.g., Sebri and Ben-Salha, 2014; Zeb et al., 2014; Shahbaz et al., 2015; Kang et al., 2016; Sinha and Sen, 2016; Wang et al., 2016, and many others). Conversely, the technical effect that is exerted by trade openness impacts economic growth positively and significantly. The coefficient of trade openness for all four cases is positive and significant, whichimplies that trade openness has a positive impact on economic growth in N-11 economies.This resultaligns with the results for Turkey (Ozturk and Acaravci, 2013), newly industrialized countries (Hossain, 2011), BRICS countries (Sinha and Sen, 2016), and several other contexts.

An empiricalanalysis of the carbon emissions function verifies the existence of anN-shaped relationship between income and CO_2 emissions (Tables 4 and 5). The coefficients$Y$, Y^2,and $Y^3$are positive, negative and positive, respectively, and are all statistically significant. This result validates the existence of N-shaped EKCs for all categories. This relationship considers that CO_2 emissions will increase with economic growth to a certain turning point, after which, emissions will decline with a sustainable level of economic growth; finally, CO_2 emissions will increase again. This N-shapedform of EKC is similar to the results reported byFriedl and Getzner

(2003), Martínez-Zarzoso and Bengochea-Morancho (2004), Galeotti et al. (2006), Egli and Steger (2007), Chuku (2011) and numerous other scholars in regard to EKC estimation for CO_2 emissions.

The resultsreported in Tables4 and 5 demonstrate that biomass energy consumption exerts a negative and significant effect on environmental quality. This indicates that biomass energy consumption first causes an increase in carbon emissions and thendeteriorates environmental quality. Numerous studies supportthe negative environmental impact of biomass energy consumption (Panayotou, 1993;Foster et al., 2000;Barbier and Burgess, 2001; Victor and Victor, 2002; Ma and Stern, 2008), and our results related to this issue are in agreement with these studies.However, this study examines the effect of the interaction between biomass energy consumption and GDP per capita on CO_2 emissions andconfirms that biomass energy consumption leads to a decline in CO_2 emissions when it is associated with increasing economic growth.This result is consistent with Foster et al. (2000) and Victor and Victor (2002). When we consider the N-11 countries, we note that rural electrification is a critical problemfor the majority of these countries (Muhammad-Sukki et al., 2012;Fathurrahman, 2016). Most of the rural areas of these nationsuse forest resources as biofuel. Burning these resources increasesthe level of CO_2 emissions. Agrawal and Malik (2008) analyzed this issue in the Indian context. To address this problem, technologically improved biomass energy solutions that are ecologically sustainable are introduced, includingbiogas and bioelectricity. Our results demonstrate that although biomass energy consumption increasesCO_2 emissions,when it is coupled with technological innovation,it significantly facilitates a reduction in CO_2 emissions.

In addition, the results of this study demonstrate that trade openness has a negative and significantimpact onCO_2 emissions. This result alignswith Jayanthakumaran et al. (2012), Shahbaz et al. (2013a), Al-Mulali et al. (2015b), and Sinha and Sen (2016) and can be justified by considering that trade openness improves environmental qualitybecause the technique effect dominates the scale effect (Ferrantino, 1997; Shahbaz et al., 2012, 2013 a, b). To corroborate this hypothesis, we employ an interaction between trade openness and GDPto analyze the effect that income exerts over trade openness and determine how it affects carbon emissions. Thisempirical finding confirms that income amplifies the positive effect that trade openness exerts on CO_2 emissions (see Figure-6).

<Insert Figure 6 here>

Figure-7illustrates the effects of the interaction between income and biomass energy consumption andbetween income and trade openness on CO_2 emissions.The empirical results reveal that when there is an interaction between income and biomass energy consumption and between income and trade openness, CO_2 emissions are reduced. To clarify, when economies increase their income levels, the negative impact of the scale effectis reduced by reducing CO_2 emissions. Theoretically, when economies increase their income levels, there is anupward economic transition from the developing stage,and this iswhen the scale effect overcomes the technique and composition effects.Once the economy reaches a certain income level, the composition and technical effects overcome the scale effect and emissions decline with ascending income levels (Torras and Boyce, 1998;Balsalobre et al., 2015). This result indicates the existence of a transition between the developing stage and the developed stage of economic development, where the scale effect on trade liberalization increases exports and subsequently enhances economic growth. To clarify, the composition effect changes the industrial structure of an economy through trade liberalization and the technique effect boosts economies to use more efficient and cleaner technologies. Consequently, a reduction in CO_2 emissionsoccurs because ofcomparative advancements in technologies and improvements in energy efficiency (Shahbaz et al., 2013;Balsalobre and Álvarez, 2016).

This study confirms that renewable energy helpsin reducing CO_2 emissions andis evidenced by the negative and significant coefficients of renewable energy consumption in Tables 4 and 5. In addition, we notea positive and significant impact of non-renewable fossil fuel consumption on CO_2 emissions. Therefore, renewable energy consumption ensures environmental protection by reducing carbon emissions, andconcurrently, non-renewable fossil fuel consumption endangers the environmental quality by increasing carbon emissions.Considering evidence that has been documented in prior studies, the results of this studyare consistent in regards to renewable energy consumption (Bölük and Mert, 2014, 2015;Bilgili et al., 2016;Dogan and Seker, 2016 a, b;Jebli et al., 2016) and non-renewable fossil fuel energy consumption (Halicioglu, 2009;Kasman and Duman, 2015;Ali et al., 2016;Dogan and Seker, 2016b;Magazzino, 2016).

The effect of urbanizationonCO_2 emissions is positive and significant and implies that the process of urbanization deteriorates environmental quality by increasing carbon emissions. This result alignswith Lin et al. (2009), Liddle (2013), Iwata and Okada (2014), Huo et al. (2015) and Shahbaz et al. (2016a). Lin et al. (2009) concluded that population is the primary factor that influences CO_2 emissions and that the level of urbanization plays a significant role. Conversely, Liddle (2013) concluded that population size and urban density are the determining factors that affect environmental quality. In a recent study, Shahbaz et al. (2016a) determined that urbanization initially resulted in low carbon emissions,and after a certain level, decreased environmental quality.

Generally, the results obtained from this study can be summarized based on the individual models. First, biomass energy consumption has a negative impact on environment, and when it is coupled with economic growth, the resultant technique effect has a positive impact on the environment. Second, income-emissions associations in all three categories of nations and in N-11 countries as a whole provide evidence for N-shaped EKCs. Third, the impact of renewable energy consumption is negative on the economic growth pattern of N-11 countries.The impact of the technique effect on environmental quality is also verified by the impact of the interaction between trade openness and economic growth on carbon emissions.

6. Conclusions and Policy Implications

This study examines the validity of the environmental Kuznets curve hypothesis in N-11 countries and analyzesrenewable and non-renewable energy consumption, biomass energy consumption, trade openness and other additional explanatory variables.The empirical resultsthat were obtained by using the Generalized Method of Moments (GMM) confirm the existence of N-shaped EKC in N-11 countries.

Our results demonstrated that renewable energy has a negative impact on economic growth,but the impact of non-renewable energy positive and significant is positive. This result is consistent with the sub-panel of emerging countries. It is evident thatN-11 nations remain dependent on non-renewable energy consumption, and because of the costs of implementing renewable energy systems, renewable energy negatively affects economic growth. However, when we analyze the sub-panels for the developed and industrialized countries, we note that renewable energy consumption has a positive impact on economic growth. This result implies that countries thatbeganrenewable energy generation processes at an earlier stagereaped the benefits. Therefore, policymakers of the emerging countries should focus on the long-term benefits of renewable energy generation and retain both renewable and non-renewable energy sources in the economic system. These countries should also emphasize technology diffusion via a trade route because it has a significant positive impact on economic growth. However, N-11 countries should placemore emphasis on renewable energy generation processes becausetheynot only providelong-term benefits on economic growth but also help these countriesachieve sustainable development goals. Implementation of this energy generation process can have a significant impact on environmental quality by reducing CO_2 emissions, which have a significant negative impact on economic growth. This ecological problem is more severe in emerging countries; compared to the other two sub-panels, these countries are faced with energy poverty issues. Successful nationwide implementation of renewable energy generation solves problemsrelated to energy poverty in these nations and can directly impact the social and ecological situations in these nations by enhancing income growth. Therefore, policymakers should overlook short-run economic lossesthat result from renewable energy generation processes and should consider this situation from a long-term perspective.

This impact is more noticeable when we compare the EKCs generated in this study. Our results demonstrate that the EKCs are N-shaped for all three sub-panels and for the N-11 countries. These results imply that the present economic growth pattern may not be ecologically sustainable because the level of emissionsincreases as income increases until it reaches the first turnaround point. If we consider the individual components of this model, it is clear that renewable energy consumption has a negative impact on CO_2 emissions, and both non-renewable and biomass energy consumptioncause an increase in CO_2 emissions. In reference to the discussion regarding energy poverty in the previous paragraph, it can be stated that the unsustainable use of biomass energy sources in rural areas increases the ambient air pollution,and its effect is similar tothe effect of non-renewable energy consumption.However, when biomass energy consumption interacts with economic growth, the interaction effect reduces CO_2 emissions. This result implies that the quality of biomass energy sourcesshould be enhanced along the course of economic growth, and this is only possible by using an inclusive growth approach. Following this approach, policymakers can reduce the usage of ecologically unsustainable biomass energy sources in rural areas, and using technology diffusioncan make high end biomass energy sources available to rural populations. In addition, the existing biomass energy sources can be replaced with new sources in a phase-wise manner; therefore, it will also be easier to complete the entire initiative without harming economic growth.It might also be possible for policymakers to replace non-renewable energy sourcesusing the same phase-wise manner to ensure that the shift from non-renewable to renewable energy sources does not harm their economic growth patterns.Clearly,new biomass energy sources should be provided to households, and renewable energy solutions should be provided to industries because the cost of renewable energy implementation is greater than for biomass energy implementation. Although countries may incur certain short-run economic losses, they may be able to receive rent from the renewable and technologically improved biomass energy sources that are provided to households and industries. These rents can add to economic growth through interest income.Governments can invest this excess income from the economic rents and use it to expand existing renewable energy generation processes. Through this process,governments may possibly achieve their renewable energy goals that were set at national levels withinspecified periods.

It should be noted that increasing rates of urbanization in these nations are exerting pressure on environmental quality. Therefore, the phase-wise shift from non-renewable to renewable energy sources may be beneficial to address increasing pressures on urban infrastructure. This phase-wise transition should have a next step where urban households are provided opportunities to procure renewable energy sources at a pro rata rate from the government. The government mayimpose interest based on the capacity of the renewable energy source, and the interest income that is received from the urban households may help the government subsidize the price of the improved biomass energy sources in rural areas. In this manner, (a) the energy poverty issue may be effectively addressed, (b) problems related to increasing CO_2 emissions can be addressed, (c) economic growth will not be harmed byimporting costly renewable energy based technologies, and (d) households and industries will be motivated to embrace the shift.

References

Abdou, D.M.S., Atya, E.M., 2013. Investigating the energy-environmental Kuznets curve: evidence from Egypt. International Journal of Green Economics, 7(2), 103-115.

Agrawal, P., Malik, S., 2008. Environmental and health impacts of biomass as an energy source. Indian Forester, 134(6), 737-743.

Al-Mulali, U., Saboori, B., Ozturk, I., 2015a. Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy Policy, 76, 123-131.

Al-Mulali, U., Solarin, S.A., Ozturk, I., 2016. Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. Natural Hazards, 80(3), 1729-1747.

Al-Mulali, U., Weng-Wai, C., Sheau-Ting, L., Mohammed, A.H., 2015b. Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. Ecological Indicators, 48, 315-323.

Ali, H.S., Law, S.H., Zannah, T.I., 2016. Dynamic impact of urbanization, economic growth, energy consumption, and trade openness on CO_2 emissions in Nigeria. Environmental Science and Pollution Research, 1-9.

Álvarez-Herranz, A., Balsalobre-Lorente D., Cantos J.M., Shahbaz M., 2017a. Energy Innovations-GHG Emissions Nexus: Fresh Empirical Evidence from OECD Countries. Energy Policy, 101, 90-100.

Álvarez-Herranz, A., Balsalobre-Lorente D., Shahbaz M., Cantos J.M., 2017b. Energy innovation and renewable energy consumption in the correction of air pollution levels. Energy Policy, 105, 386-397.

Andreoni, J., Levinson, A., 2001. The simple analytics of the environmental Kuznets curve. Journal of Public Economics, 80(2), 269-286.

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. Journal of Econometrics, 68(1), 29-51.

Baek, J., Kim, H.S., 2011. Trade liberalization, economic growth, energy consumption and the environment: Time series evidence from G-20 economies. Journal of East Asian Economic Integration, 15(1), 3-32.

Balsalobre, D., Álvarez, A., Cantos, J.M., 2015. Public budgets for energy RD&D and the effects on energy intensity and pollution levels. Environmental Science and Pollution Research, 22(7), 4881-4892.

Balsalobre, D. Alvarez, A., 2016. An Approach to the Effect of Energy Innovation on Environmental Kuznets Curve: An Introduction to Inflection Point. Bulletin of Energy Economics 4(3), 224-233.

Barbier, E.B., Burgess, J.C., 2001. The economics of tropical deforestation. Journal of Economic Surveys, 15(3), 413-433.

Bello, A.K., Abimbola, O.M., 2010. Does the level of economic growth influence environmental quality in Nigeria: A test of environmental Kuznets curve (EKC) hypothesis. Pakistan Journal of Social Sciences, 7(4), 325-329.

Bildirici, M.E., 2013. Economic growth and biomass energy. Biomass and Bioenergy, 50, 19-24.

Bilgili, F., Koçak, E., Bulut, Ü., 2016. The dynamic impact of renewable energy consumption on CO_2 emissions: a revisited Environmental Kuznets Curve approach. Renewable and Sustainable Energy Reviews, 54, 838-845.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics, 87(1), 115-143.

Bölük, G., Mert, M., 2014. Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. Energy, 74, 439-446.

Bölük, G., Mert, M., 2015. The renewable energy, growth and environmental Kuznets curve in Turkey: an ARDL approach. Renewable and Sustainable Energy Reviews, 52, 587-595.

Bovenberg, A.L., Smulders, S., 1995. Environmental quality and pollution-augmenting technological change in a two-sector endogenous growth model. Journal of Public Economics, 57(3), 369-391.

Breitung, J., 2002. Nonparametric tests for unit roots and cointegration. Journal of Econometrics, 108(2), 343-363.

Carson, R.T., Jeon, Y., McCubbin, D.R., 1997. The relationship between air pollution emissions and income: US data. Environment and Development Economics, 2(4), 433-450.

Chen, J.H., Huang, Y.F., 2013. The study of the relationship between carbon dioxide (CO_2) emission and economic growth. Journal of International and Global Economic Studies, 6(2), 45-61.

Chuku, A., 2011. Economic development and environmental quality in Nigeria: is there an environmental Kuznets curve?. Department of Economics, University of Uyo.

Cole, M.A., Neumayer, E., 2004. Examining the impact of demographic factors on air pollution. Population and Environment, 26(1), 5-21.

De Bruyn, S.M., van den Bergh, J.C., Opschoor, J.B., 1998. Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves. Ecological Economics, 25(2), 161-175.

Destek, M.A., Balli, E., Manga, M., 2016. The Relationship between CO_2 Emission, Energy Consumption, Urbanization and Trade Openness for Selected CEECs. Research in World Economy, 7(1), 52-58.

Diao, X.D., Zeng, S.X., Tam, C.M., Tam, V.W., 2009. EKC analysis for studying economic growth and environmental quality: a case study in China. Journal of Cleaner Production, 17(5), 541-548.

Dogan, E., Seker, F., 2016a. The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renewable and Sustainable Energy Reviews, 60, 1074-1085.

Dogan, E., Seker, F., 2016b. Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. Renewable Energy, 94, 429-439.

Eghbal, M., 2008. The Next 11 Emerging Economies. Euromonitor International. Retrieved from: http://blog.euromonitor.com/2008/02/the-next-11-emerging-economies.html.

Egli, H., Steger, T.M., 2007. A dynamic model of the environmental Kuznets curve: turning point and public policy. Environmental and Resource Economics, 36(1), 15-34.

Energy Information Administration (EIA), 2015. International Energy Outlook. EIA, Washington, DC, Available from: www.eia.gov/forecasts/aeo

Farhani, S., Shahbaz, M., 2014. What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO_2 emissions in MENA region?. Renewable and Sustainable Energy Reviews, 40, 80-90.

Fathurrahman, F., 2016. Measuring the sustainability of energy development in emerging economies. International Journal of Global Environmental Issues, 15(4), 315-345.

Feridun, M., Ayadi, F.S., Balouga, J., 2006. Impact of Trade Liberalization on the Environment in Developing Countries The Case of Nigeria. Journal of Developing Societies, 22(1), 39-56.

Ferrantino, M.J., 1997. International trade, environmental quality and public policy. The World Economy, 20(1), 43-72.

Foster, V., Tre, J.P., Wodon, Q., 2000. Energy consumption and income: An inverted-U at the household level. World Bank, Washington.

Frankel, J.A., Rose, A.K., 2005. Is trade good or bad for the environment? Sorting out the causality. Review of Economics and Statistics, 87(1), 85-91.

Friedl, B., Getzner, M., 2003. Determinants of CO_2 emissions in a small open economy. Ecological Economics, 45(1), 133-148.

Galeotti, M., Lanza, A., Pauli, F., 2006. Reassessing the environmental Kuznets curve for CO_2 emissions: a robustness exercise. Ecological Economics, 57(1), 152-163.

Gallagher, K.P., 2005. Economic Integration and the Environment in Mexico. Center for Latin American Studies.

Gradus, R., Smulders, S., 1993. The trade-off between environmental care and long-term growth—pollution in three prototype growth models. Journal of Economics, 58(1), 25-51.

Grossman, G.M., Krueger, A.B., 1991. Environmental impacts of a North American free trade agreement (No. w3914). National Bureau of Economic Research.

Grossman, G.M., Krueger, A.B., 1995. Economic growth and the environment. Quarterly Journal of Economics, 110(2), 353-377.

Halicioglu, F., 2009. An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy, 37(3), 1156-1164.

Halkos, G.E., 2003. Environmental Kuznets Curve for sulfur: evidence using GMM estimation and random coefficient panel data models. Environment and Development Economics, 8(4), 581-601.

Hassan, K., Salim, R., 2015. Population ageing, income growth and CO_2 emission: Empirical evidence from high income OECD countries. Journal of Economic Studies, 42(1), 54-67.

He, Z., Xu, S., Shen, W., Long, R., Chen, H., 2017. Impact of urbanization on energy related CO_2 emission at different development levels: Regional difference in China based on panel estimation. Journal of Cleaner Production, 140, 1719-1730.

Hettige, H., Mani, M., Wheeler, D., 2000. Industrial pollution in economic development: the environmental Kuznets curve revisited. Journal of Development Economics, 62(2), 445-476.

Hossain, M.S., 2011. Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy, 39(11), 6991-6999.

Huo, J., Yang, D., Zhang, W., Wang, F., Wang, G., Fu, Q., 2015. Analysis of influencing factors of CO_2 emissions in Xinjiang under the context of different policies. Environmental Science & Policy, 45, 20-29.

Ibrahim, M.H., Law, S.H., 2015. Institutional Quality and CO_2 Emission–Trade Relations: Evidence from Sub-Saharan Africa. South African Journal of Economics, 84(2), 323-340.

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115(1), 53-74.

Iwata, H., Okada, K., 2014. Greenhouse gas emissions and the role of the Kyoto Protocol. Environmental Economics and Policy Studies, 16(4), 325-342.

Jayanthakumaran, K., Verma, R., Liu, Y., 2012. CO_2 emissions, energy consumption, trade and income: a comparative analysis of China and India. Energy Policy, 42, 450-460.

Jebli, M.B., Youssef, S.B., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators, 60, 824-831.

Jegannathan, K.R., Nielsen, P.H., 2013. Environmental assessment of enzyme use in industrial production–a literature review. Journal of Cleaner Production, 42, 228-240.

Jones, L., Manuelli, R., 1995. A Positive Model of Growth and Pollution Controls (No. w5205). National Bureau of Economic Research.

Kang, Y.Q., Zhao, T., Wu, P., 2016. Impacts of energy-related CO_2 emissions in China: a spatial panel data technique. Natural Hazards, 81(1), 405-421.

Kasman, A., Duman, Y.S., 2015. CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Economic Modelling, 44, 97-103.

Kim, S., Jung, K.H., 2014. EKC Hypothesis Testing for the CO_2 Emissions of Korea Considering Total Factor Productivity: Focusing on the CO_2 Emissions by Region and GRDP. Environmental and Resource Economics Review, 23(4), 667-688.

Levin, A., Lin, C.F., Chu, C.S.J., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics, 108(1), 1-24.

Liddle, B., 2013. Population, affluence, and environmental impact across development: evidence from panel cointegration modeling. Environmental Modelling & Software, 40, 255-266.

Lin, S., Zhao, D., Marinova, D., 2009. Analysis of the environmental impact of China based on STIRPAT model. Environmental Impact Assessment Review, 29(6), 341-347.

Ling, C.H., Ahmed, K., Muhamad, R.B., Shahbaz, M., 2015. Decomposing the trade-environment nexus for Malaysia: what do the technique, scale, composition, and comparative advantage effect indicate?. Environmental Science and Pollution Research, 22(24), 20131-20142.

Lorek, S., Fuchs, D., 2013. Strong sustainable consumption governance–precondition for a degrowth path?. Journal of Cleaner Production, 38, 36-43.

Ma, C., Stern, D.I., 2008. Biomass and China's carbon emissions: A missing piece of carbon decomposition. Energy Policy, 36(7), 2517-2526.

Maddala, G.S., Wu, S., 1999. A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and statistics, 61(S1), 631-652.

Magazzino, C., 2016. The relationship between CO_2 emissions, energy consumption and economic growth in Italy. International Journal of Sustainable Energy, 35(9), 844-857.

Martínez-Zarzoso, I., Bengochea-Morancho, A., 2004. Pooled mean group estimation of an environmental Kuznets curve for CO_2. Economics Letters, 82(1), 121-126.

Martínez-Zarzoso, I., Maruotti, A., 2011. The impact of urbanization on CO_2 emissions: evidence from developing countries. Ecological Economics, 70(7), 1344-1353.

Meng, F., Su, B., Thomson, E., Zhou, D., Zhou, P., 2016. Measuring China's regional energy and carbon emission efficiency with DEA models: A survey. Applied Energy, 183, 1-21.

Moomaw, W.R., Unruh, G.C., 1997. Are environmental Kuznets curves misleading us? The case of CO_2 emissions. Environment and Development Economics, 2(4), 451-463.

Muhammad-Sukki, F., Munir, A.B., Ramirez-Iniguez, R., Abu-Bakar, S.H., Yasin, S.H.M., McMeekin, S.G., Stewart, B.G., 2012. Solar photovoltaic in Malaysia: the way forward. Renewable and Sustainable Energy Reviews, 16(7), 5232-5244.

Nahman, A., Antrobus, G, 2005. Trade and the environmental Kuznets curve: is Southern Africa a pollution haven? South African Journal of Economics, 73(4), 803-814.

Ozcan, B., 2013. The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: A panel data analysis. Energy Policy, 62, 1138-1147.

Ozturk, I., 2010. A literature survey on energy–growth nexus. Energy Policy, 38(1), 340-349.

Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics, 36, 262-267.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics, 22(2), 265-312.

Rabbi, F., Akbar, D., Kabir, S.Z., 2015. Environment Kuznets Curve for Carbon Emissions: A Cointegration Analysis for Bangladesh. International Journal of Energy Economics and Policy, 5(1), 45-53.

Renewable Energy Policy Network for the 21st Century (REN21), 2016. Renewables 2013 Global Status Report. Paris.

Riti, J.S., Song, D., Shu, Y., Kamah, M., 2017. Decoupling CO_2 emission and economic growth in China: Is there consistency in estimation results in analyzing environmental Kuznets curve?. Journal of Cleaner Production, (forthcoming).

Saboori, B., Sulaiman, J.B., Mohd, S., 2012. An empirical analysis of the environmental Kuznets curve for CO_2 emissions in Indonesia: the role of energy consumption and foreign trade. International Journal of Economics and Finance, 4(2), 243.

Sebri, M., Ben-Salha, O., 2014. On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions and trade openness: fresh evidence from BRICS countries. Renewable and Sustainable Energy Reviews, 39, 14-23.

Seriño, M.N.V., 2014. Do Philippine households lead a carbon intensive lifestyle?. Courant Research Centre: Poverty, Equity and Growth-Discussion Papers (No. 158).

Sghari, M.B.A., Hammami, S., 2016. Energy, pollution and economic development in Tunisia. Energy Reports, 2, 35-39.

Shafik, N., Bandyopadhyay, S., 1992. Economic Growth and Environmental Quality Time-series and Cross-Country Evidence. World Bank Working Papers 904, 1-6, Washington D.C.

Shahbaz, M., 2013. Does financial instability increase environmental degradation? Fresh evidence from Pakistan. Economic Modelling, 33, 537-544.

Shahbaz, M., Lean, H.H., Shabbir, M.S., 2011. Environmental Kuznets curve and the role of energy consumption in Pakistan. Development Research Unit, Monash University.

Shahbaz, M., Lean, H.H., Shabbir, M.S., 2012. Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. Renewable and Sustainable Energy Reviews, 16(5), 2947-2953.

Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., Leitão, N.C., 2013a. Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renewable and Sustainable Energy Reviews, 25, 109-121.

Shahbaz, M., Ozturk, I., Afza, T., Ali, A., 2013b. Revisiting the environmental Kuznets curve in a global economy. Renewable and Sustainable Energy Reviews, 25, 494-502.

Shahbaz, M., Uddin, G.S., Rehman, I.U., Imran, K., 2014. Industrialization, electricity consumption and CO_2 emissions in Bangladesh. Renewable and Sustainable Energy Reviews, 31, 575-586.

Shahbaz, M., Dube, S., Ozturk, I., Jalil, A., 2015. Testing the environmental Kuznets curve hypothesis in Portugal. International Journal of Energy Economics and Policy, 5(2), 475-481.

Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., Jabran, M.A., 2016a. How urbanization affects CO_2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews, 57, 83-93.

Shahbaz, M., Mahalik, M.K., Shah, S.H., Sato, J.R., 2016b. Time-varying analysis of CO_2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. Energy Policy, 98, 33-48.

Sinha, A., 2015. Modeling Energy Efficiency and Economic Growth: Evidences from India. International Journal of Energy Economics and Policy. 5(1), 96-104.

Sinha, A., Bhattacharya, J., 2016. Environmental Kuznets Curve estimation for NO_2 emission: A case of Indian cities. Ecological Indicators, 67, 1-11.

Sinha, A., Bhattacharya, J., 2017. Environmental Kuznets Curve estimation for SO_2 emission: A case of Indian cities. Ecological Indicators, 72, 881-894.

Sinha, A., Sen, S., 2016. Atmospheric consequences of trade and human development: A case of BRIC countries. Atmospheric Pollution Research, 7(6), 980-989.

Stern, D.I., 2007. The effect of NAFTA on energy and environmental efficiency in Mexico. Policy Studies Journal, 35, 291–322.

Sugiawan, Y., Managi, S., 2016. The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy. Energy Policy, 98, 187-198.

Suri, V., Chapman, D., 1998. Economic growth, trade and energy: implications for the environmental Kuznets curve. Ecological Economics, 25(2), 195-208.

Tang, C.F., Tan, B.W., 2015. The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy, 79, 447-454.

Torras, M., Boyce, J.K., 1998. Income, inequality, and pollution: a reassessment of the environmental Kuznets curve. Ecological Economics, 25(2), 147-160.

United Nations (UN), 2015. World Population Prospects: The 2015 Revision. Population Division, Department of Economic and Social Affairs, United Nations, New York.

UNFCCC, 2015. United Nations Framework Convention on Climate Change. Paris Climate Change Conference (COP21), November 2015.

van den Bergh, J.C., Nijkamp, P., 1994. Dynamic macro modelling and materials balance: Economic-environmental integration for sustainable development. Economic Modelling, 11(3), 283-307.

Verdier, T., 1993. Environmental pollution and endogenous growth A comparison between emission taxes and technological standards. Fondazione Eni Enrico Mattei. Discussion Paper 57.

Victor, N.M., Victor, D.G., 2002. Macro patterns in the use of traditional biomass fuels. Program on Energy and Sustainable Development, Publication Number WP-10, Stanford University.

Wang, Y., Chen, L., Kubota, J., 2016a. The relationship between urbanization, energy use and carbon emissions: evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries. Journal of Cleaner Production, 112, 1368-1374.

Wang, Y., Yang, X., Sun, M., Ma, L., Li, X., Shi, L., 2016b. Estimating carbon emissions from the pulp and paper industry: A case study. Applied Energy, 184, 779-789.

Wang, Z., Yin, F., Zhang, Y., Zhang, X., 2012. An empirical research on the influencing factors of regional CO_2 emissions: evidence from Beijing city, China. Applied Energy, 100, 277-284.

World Bank, 2016. World Bank Country and Lending Groups. Retrieved from https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

Wyckoff, A.W., Roop, J.M., 1994. The embodiment of carbon in imports of manufactured products: implications for international agreements on greenhouse gas emissions. Energy Policy, 22(3), 187-194.

Zeb, R., Salar, L., Awan, U., Zaman, K., Shahbaz, M., 2014. Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: Progress towards green economy. Renewable Energy, 71, 123-132.

Zeng, S., Nan, X., Liu, C., Chen, J., 2017a. The response of the Beijing carbon emissions allowance price (BJC) to macroeconomic and energy price indices. Energy Policy, 106, 111-121.

Zeng, S., Liu, Y., Liu, C., Nan, X.,2017b. A review of renewable energy investment in the BRICS countries: History, models, problems and solutions. Renewable and Sustainable Energy Reviews, 74, 860-872.

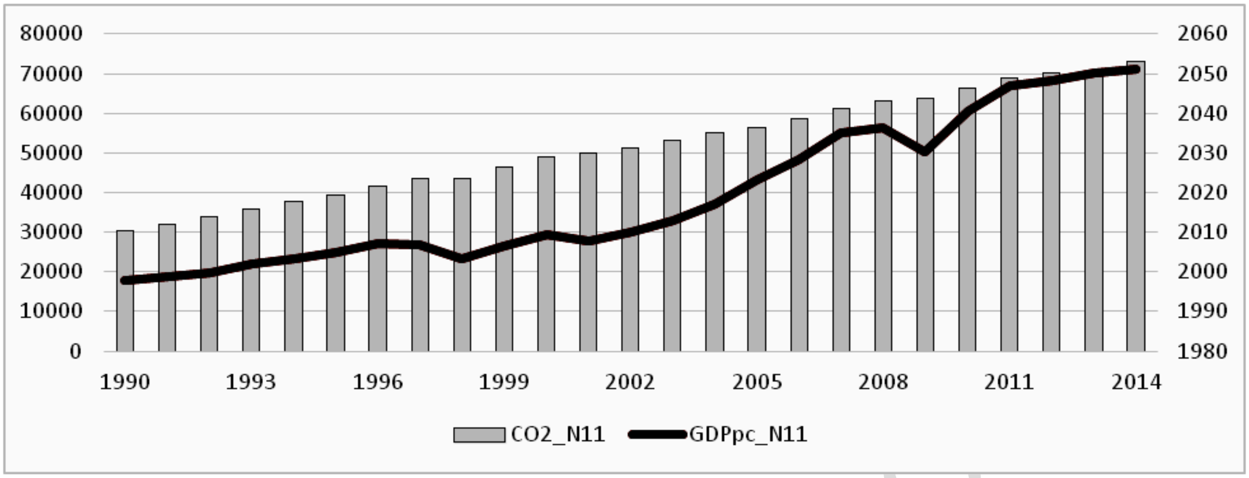


Figure-1: Evolution of per capita GDP and CO_2 emissions in N-11 countries

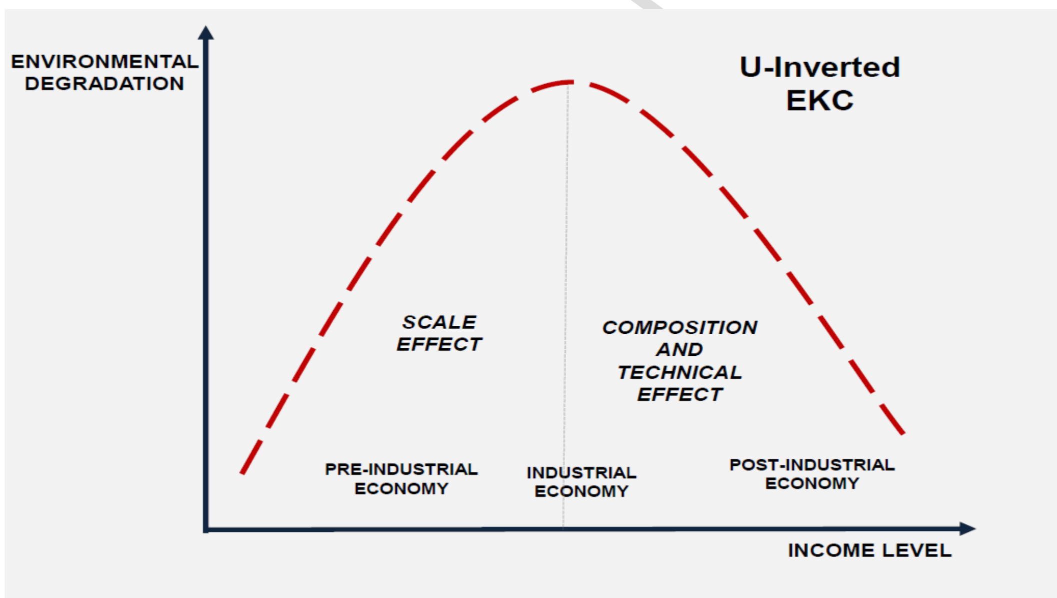


Figure-2: Inverted U-shaped EKC: Demonstrating scale, composition and technique effects (Source: Halkos, 2003)

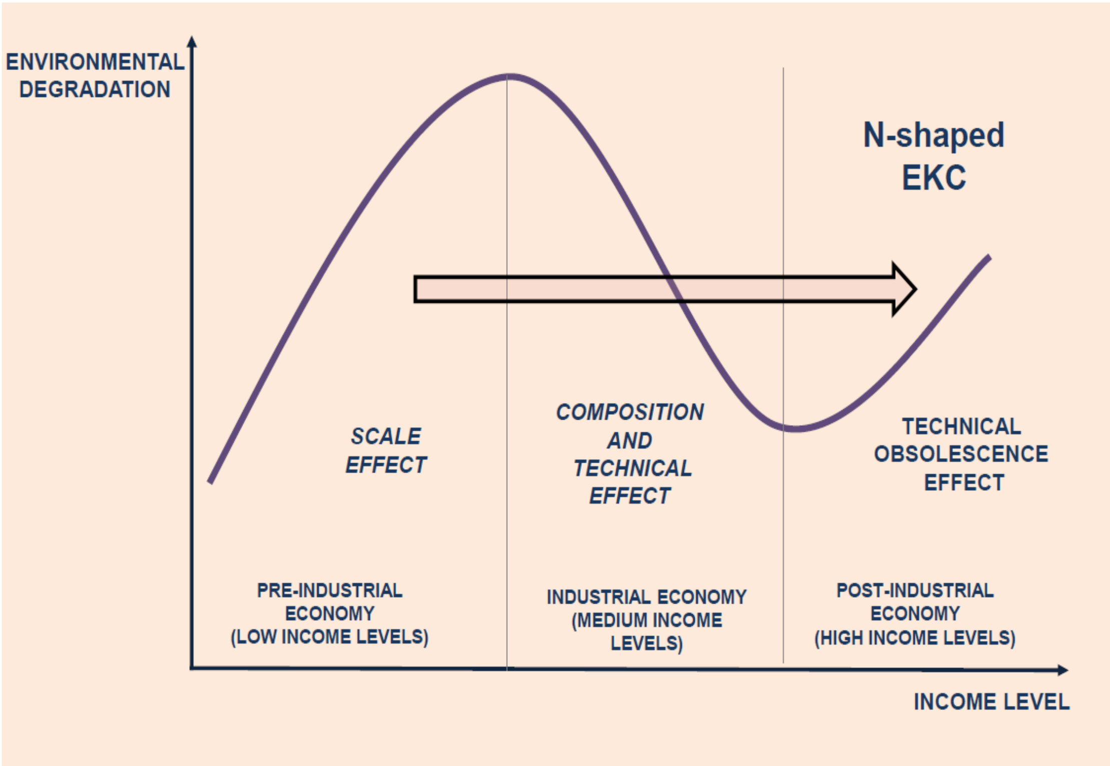


Figure-3: N-shaped EKC and Technical Obsolescence Effect

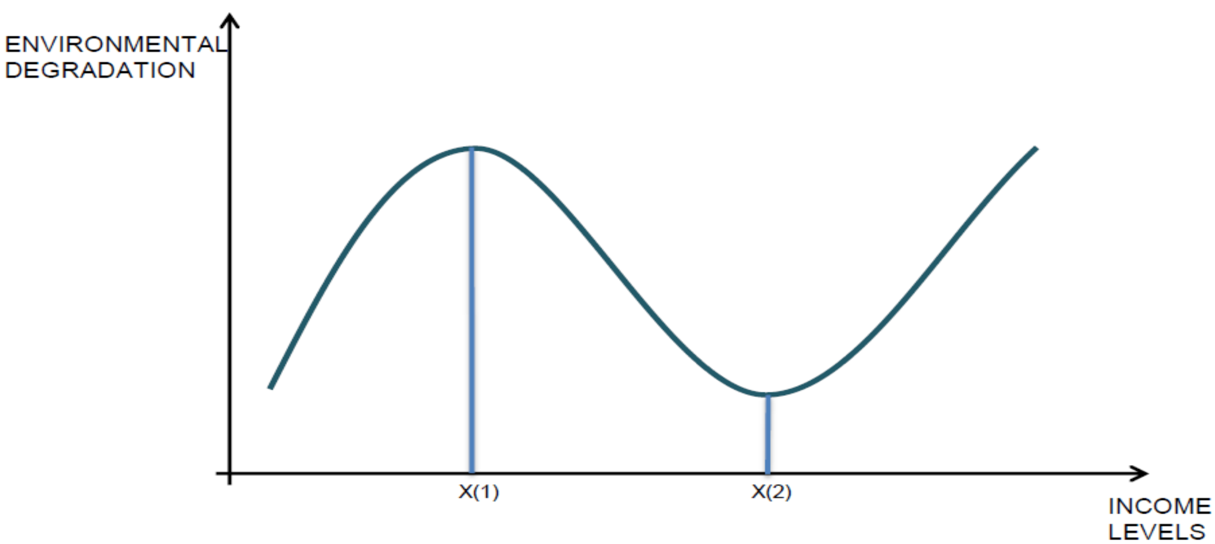


Figure-4: Turning Points of an N-shaped EKC model

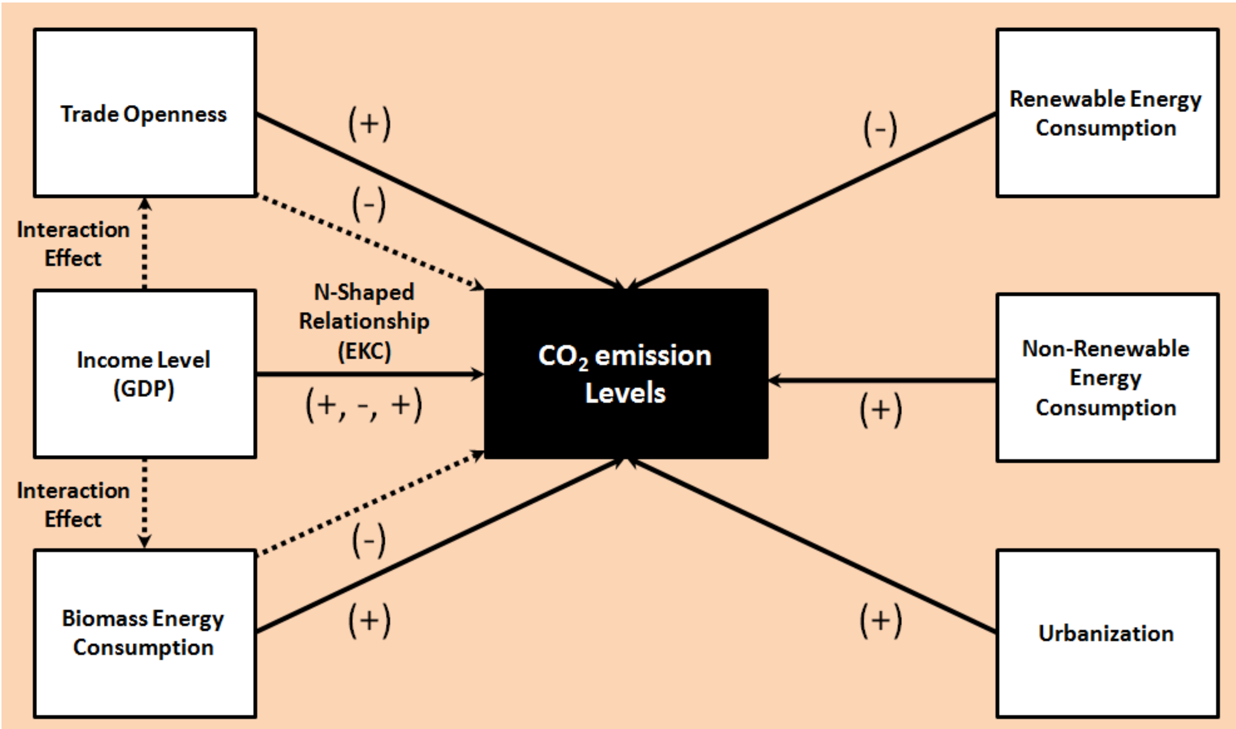


Figure-5: Conceptual Scheme

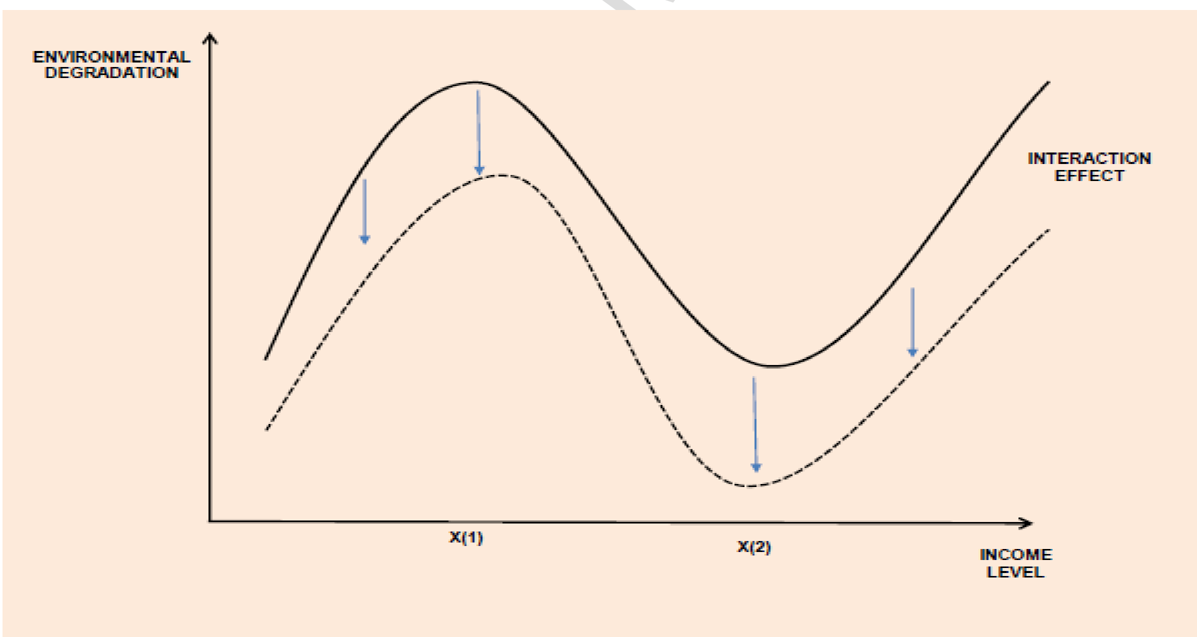
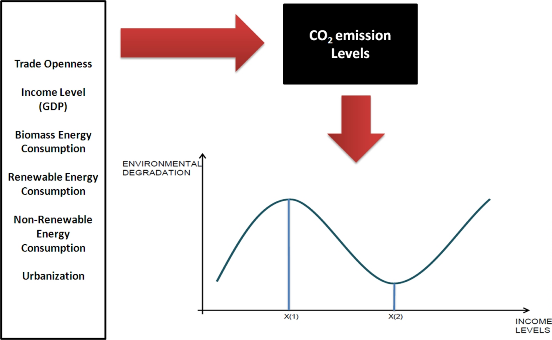


Figure-6: Interaction effect (Interaction Variable and CO_2 emission levels)



Trade Openness
Income Level (GDP)
Biomass Energy Consumption
Renewable Energy Consumption
Non-Renewable Energy Consumption
Urbanization
CO2 emission Levels
ENVIRONMENTAL DEGRADATION
X(1)
X(2)
INCOME LEVELS

Table-1: Results of Cross Section Dependence Tests

Variables	Lags			
	1	2	3	4
Y	2.252 (0.988)	0.390 (0.652)	1.361 (0.913)	1.976 (0.989)
Y^2	-0.693 (0.244)	-0.245 (0.403)	-0.134 (0.447)	1.246 (0.894)
Y^3	1.959 (0.975)	-0.147 (0.442)	1.601 (0.945)	1.891 (0.981)
R	-0.588 (0.278)	-0.859 (0.195)	0.128 (0.551)	-1.448 (0.774)
B	-0.372 (0.355)	0.465 (0.679)	0.617 (0.731)	0.081 (0.532)
N	-1.154 (0.124)	-1.063 (0.144)	2.021 (0.978)	1.007 (0.843)
L	-0.986 (0.162)	-1.086 (0.139)	-1.112 (0.133)	0.447 (0.673)
H	-0.812 (0.208)	-0.718 (0.236)	1.485 (0.931)	0.435 (0.668)
T	0.369 (0.644)	0.969 (0.834)	2.118 (0.983)	2.722 (0.997)
C	-0.651 (0.258)	-0.189 (0.425)	1.154 (0.876)	0.622 (0.733)
W	0.137 (0.555)	2.104 (0.982)	2.089 (0.980)	1.778 (0.962)
U	-0.868 (0.193)	0.235 (0.593)	1.228 (0.890)	0.662 (0.746)
K	1.161 (0.877)	0.244 (0.596)	2.741 (0.997)	0.107 (0.542)
BY	-1.055 (0.146)	-0.069 (0.473)	0.778 (0.782)	1.368 (0.914)
TY	0.210 (0.583)	2.353 (0.991)	2.747 (0.997)	1.674 (0.967)
Note: p-values appear in parentheses				

Table-2: Results of Unit Root Tests

Variables	LLC		Breitung		IPS		Fisher-ADF	
	Level	First Diff.	Level	First Diff.	Level	First Diff.	Level	First Diff.
Developed Countries								
Y	-0.5729	-3.3037[a]	1.2530	-2.7487[a]	0.4572	-2.4033[a]	-0.6742	6.5531[a]
Y^2	-0.4923	-3.3550[a]	1.3041	-2.8202[a]	0.5959	-2.3806[a]	-0.7290	6.6584[a]
Y^3	-0.4066	-3.4051[a]	1.3558	-2.8859[a]	0.7365	-2.3570[a]	-0.7755	6.7630[a]
R	0.2810	-1.5068[c]	0.3229	-3.5016[a]	1.6719	-2.5964[a]	-0.9398	3.7739[a]
B	-0.8434	-3.5277[a]	-2.4708	-3.0011[a]	-0.4503	-3.2339[a]	-0.8108	10.6910[a]
N	-0.3872	-3.0568[a]	2.6329	-2.6077[a]	-1.1943	-2.1163[b]	0.4910	4.7589[a]
L	-0.5779	-1.9926[b]	3.0131	-1.7357[b]	-0.8824	-2.3168[b]	0.8048	2.4694[a]
H	-0.7445	-1.9594[b]	1.7488	-3.1667[a]	0.3792	-2.4172[a]	-0.6451	3.0186[a]
T	-0.0305	-3.0724[a]	0.7201	-3.0020[a]	1.1635	-2.7994[a]	-0.9021	6.1595[a]
C	-0.8452	-2.9080[a]	1.3967	-3.2680[a]	-0.7103	-2.5477[a]	0.5595	5.5073[a]
W	-0.0685	-3.6020[a]	2.1965	-1.7612[b]	1.5452	-2.8167[a]	-0.9407	3.2312[a]
U	-0.7399	-1.4827[c]	2.9874	-2.2423[b]	-0.0759	-1.3836[c]	-0.1259	1.8205[b]
K	-0.8788	-4.0956[a]	-0.0190	-2.8429[a]	-0.1491	-2.5332[a]	-0.2524	9.9442[a]
BY	-0.6655	-3.6147[a]	0.1576	-3.0597[a]	-1.2785	-3.2436[a]	0.5476	11.0563[a]
TY	0.2135	-3.3398[a]	2.0148	-3.4404[a]	1.6118	-2.7424[a]	-0.9482	7.7588[a]
Industrialized Countries								
Y	0.0229	-3.6541[a]	2.4486	-3.6450[a]	2.6168	-5.3631[a]	-1.6846	8.3907[a]
Y^2	0.1925	-3.4830[a]	2.6064	-3.6808[a]	2.9123	-5.2366[a]	-1.7107	7.9994[a]
Y^3	0.3546	-3.3238[a]	2.7584	-3.7425[a]	3.1993	-5.0954[a]	-1.7266	7.6296[a]
R	0.9828	-3.3176[a]	1.4566	-6.1163[a]	-0.8961	-5.0692[a]	1.2492	7.2426[a]
B	-1.2209	-4.3292[a]	1.3980	-5.0398[a]	-0.6487	-5.9289[a]	1.2817	13.7069[a]
N	0.5445	-4.1168[a]	2.1861	-4.6930[a]	-1.0269	-5.2095[a]	0.6419	8.6043[a]
L	2.3139	-1.8262[b]	1.5830	-6.0380[a]	0.7082	-4.7353[a]	-0.9385	4.9191[a]
H	-1.1940	-2.8423[a]	3.4402	-7.1301[a]	1.2855	-5.3279[a]	-1.6770	5.1884[a]
T	-1.2010	-5.9655[a]	-0.1583	-5.9149[a]	-0.1412	-5.5661[a]	-0.0595	13.5421[a]
C	-1.2181	-6.3487[a]	2.0439	-6.7795[a]	0.1520	-6.1940[a]	-0.7152	15.4026[a]
W	-0.7154	-3.7748[a]	1.6145	-5.1366[a]	-1.2776	-5.6381[a]	-0.2432	10.3039[a]
U	-0.5726	-2.1568[b]	1.3819	-3.1752[a]	2.0513	-5.0786[a]	-1.4043	2.1284[b]
K	-0.2948	-5.4156[a]	0.1851	-4.5120[a]	1.5778	-5.6748[a]	-1.5123	11.8199[a]
BY	-0.6276	-4.0674[a]	0.2418	-5.3437[a]	-0.7787	-5.6959[a]	1.1550	12.7001[a]
TY	-1.2515	-6.1922[a]	2.5712	-4.3967[a]	1.3008	-5.7259[a]	-0.0639	13.9822[a]
Emerging Countries								
Y	-0.0234	-1.9909[b]	4.5974	-2.5974[a]	3.6927	-5.3962[a]	-1.8818	4.8976[a]
Y^2	1.1225	-2.3846[a]	5.0279	-2.9358[a]	4.7518	-5.2286[a]	-2.0247	4.9987[a]
Y^3	2.2720	-2.6667[a]	5.3899	-3.2920[a]	5.8948	-4.9844[a]	-2.0824	4.9303[a]
R	2.2284	-2.7309[a]	2.4903	-4.5327[a]	-0.9073	-4.3026[a]	-0.1502	9.4907[a]
B	1.7682	-4.0158[a]	2.1794	-6.0226[a]	-0.8702	-5.8361[a]	0.7067	12.4213[a]
N	0.9829	-1.3798[c]	5.7092	-3.3468[a]	0.5507	-4.1529[a]	0.6977	4.2420[a]
L	2.5863	-1.4873[c]	8.1210	-1.9522[b]	0.0656	-2.0645[b]	-1.3032	3.3117[a]

H	-1.1329	-3.0184[a]	2.9104	-7.1068[a]	1.2365	-5.2835[a]	-1.6251	5.6031[a]
T	0.2611	-3.3428[a]	0.6741	-3.8306[a]	-0.6340	-6.4632[a]	0.4668	13.2436[a]
C	-0.7859	-3.9463[a]	3.6792	-4.9761[a]	1.3341	-5.4835[a]	-1.0262	10.0346[a]
W	-0.4025	-4.6784[a]	4.0015	-4.8021[a]	0.1318	-5.5145[a]	-1.2754	10.2593[a]
U	-0.4539	-1.9644[b]	9.1770	-1.5714[c]	2.8750	-2.3449[b]	-1.8536	3.5857[a]
K	-0.2194	-2.3711[a]	4.2688	-2.0915[b]	2.6367	-4.7204[a]	-0.8536	4.9093[a]
BY	-0.4287	-3.8966[a]	3.6075	-7.5379[a]	1.2039	-5.9106[a]	-0.9433	11.9067[a]
TY	-0.0368	-5.4397[a]	3.6014	-6.6455[a]	2.7927	-5.6162[a]	-1.9963	13.9216[a]
N-11 Countries Panel								
Y	-0.1077	-4.5434[a]	5.3229	-4.6917[a]	4.3917	-7.9785[a]	-2.6374	10.9348[a]
Y^2	0.9811	-4.7657[a]	5.7577	-5.0365[a]	5.3468	-7.7734[a]	-2.7605	10.7709[a]
Y^3	2.0598	-4.8916[a]	6.1261	-5.3862[a]	6.3533	-7.5064[a]	-2.8181	10.5070[a]
R	0.4324	-4.5215[a]	2.8728	-6.3729[a]	-1.0862	-7.1013[a]	1.0015	12.4195[a]
B	-1.2777	-6.6165[a]	2.4300	-8.2328[a]	-1.2698	-8.9071[a]	0.3586	20.8390[a]
N	-0.2034	-4.4527[a]	8.8157	-5.7950[a]	-0.6811	-6.9502[a]	1.1898	10.0958[a]
L	0.6724	-2.1716[b]	0.8702	-3.8961[a]	0.2557	-5.2830[a]	-1.5585	6.2938[a]
H	0.6513	-4.5495[a]	4.8307	-10.5524[a]	1.8146	-7.8830[a]	-2.4325	8.1858[a]
T	3.2149	-7.2013[a]	0.6100	-6.9312[a]	-0.1719	-8.9542[a]	0.4186	19.9161[a]
C	-0.8819	-7.6818[a]	4.4034	-8.6767[a]	0.7878	-8.6411[a]	-0.9698	18.8103[a]
W	0.2796	-5.8142[a]	4.7443	-7.1429[a]	-0.3066	-8.3684[a]	-0.0429	14.8379[a]
U	4.4944	-1.9227[b]	2.7076	-3.9162[a]	5.4363	-1.9868[b]	-2.0217	3.4356[a]
K	-0.4204	-5.8933[a]	3.9804	-4.4382[a]	2.7965	-7.7722[a]	-1.7325	14.2771[a]
BY	-0.6993	-6.3899[a]	3.2352	-9.2020[a]	-0.0988	-8.8031[a]	0.1224	19.9235[a]
TY	-0.9875	-8.8266[a]	4.8002	-7.8833[a]	3.2458	-8.4737[a]	-1.6744	21.1521[a]
Note: a value at 1% significance level. b value at 5% significance level. c value at 1% significance level								

Table-3: GMM Analysis of Production Function

Independent Variables	Dependent variable = Y			
	Developed Countries	Industrialized Countries	Emerging Countries	N-11 Countries Panel
R	0.0092[a]	0.2072[a]	-1.0304[a]	-2.2628[a]
B	0.0431[a]	0.3213[a]	1.3721[a]	1.7111[a]
N	0.9503[a]	0.2553[b]	0.6305[a]	2.0649[a]
L	0.0884[a]	0.0446[b]	0.6298[a]	0.5988[b]
H	0.0080	0.6815[b]	0.2230	-1.4560[a]
T	0.0514[c]	2.1336[b]	0.9536[a]	1.6870[a]
W	0.0117	-0.0128[a]	0.3659	-1.6598[a]
K	1.5305[a]	1.2841[a]	0.4916[a]	1.9720[a]
C	-0.0025[b]	-0.2431[c]	-2.2758[a]	-1.1339[a]
Constant	2.3364[a]	2.6199[a]	6.5458[b]	4.9251[a]
Hansen's J statistics	0.2753	0.3541	0.6223	0.2489
DWH Test statistics	6.4841[b]	17.5110[a]	16.0889[a]	16.4168[a]
Note: a value at 1% significance level. b value at 5% significance level. c value at 10% significance level				

Table-4: GMM Analysis of Carbon Emissions Function with Growth and Biomass Energy Consumption Interaction

Independent Variables	Dependent variable = C			
	Developed Countries	Industrialized Countries	Emerging Countries	N-11 Countries Panel
Y	1.3455[b]	0.8184[a]	1.0346[a]	0.3831[a]
Y^2	-0.5019[b]	-0.9183[b]	-0.0436[b]	-0.2087[a]
Y^3	0.0368[a]	0.0469[c]	0.0776[a]	0.3116[c]
R	-0.0665[a]	-0.2671[a]	-0.1927[a]	-0.2137[c]
B	2.0567[c]	2.2295[a]	1.8922[a]	1.8007[a]
N	0.5115[b]	0.6707[a]	0.2876[a]	1.1384[a]
T	-0.2520[a]	-0.3308[a]	0.1931[a]	-1.2160[b]
U	2.3268[a]	0.2616[a]	0.1147[b]	0.8759[a]
B*Y	-2.9567[c]	-1.4217[a]	-1.1067[a]	-1.3989[a]
Constant	6.3176[a]	2.2378[b]	6.6956[a]	7.4568[a]
Hansen's J statistics	1.1217	0.5447	1.4360	0.4217
DWH Test statistics	7.7606[a]	7.4287[a]	7.0726[a]	10.0351[b]
Shape of EKC	N-shaped	N-shaped	N-shaped	N-shaped
Turnaround point(s)	a) 7.79 b) 1555.81	a) 7.64 b) 5379.50	a) 1.08 b) 6902.47	a) 1.98 b) 1562.33
Note: a value at 1% significance level. b value at 5% significance level. c value at 10% significance level				

Table-5: GMM Analysis of Carbon Emissions Function with Growth and Trade Openness Interaction

Independent Variables	Dependent variable = C			
	Developed Countries	Industrialized Countries	Emerging Countries	N-11 Countries Panel
Y	1.9992[a]	1.5339[a]	1.0051[a]	0.5155[a]
Y^2	-0.0524[a]	-0.0234[a]	-0.1083[b]	-0.1926[a]
Y^3	0.0728[a]	0.1329[b]	0.0281[a]	0.0056[a]
R	-0.1248[a]	-0.0948[b]	-0.3719[a]	-0.0120[a]
B	0.0150	0.2223	1.3062[a]	0.0250[a]
N	0.8844[a]	0.7122[a]	0.3739[a]	0.0108[a]
T	-6.6538[a]	-0.5421[c]	1.7451[a]	-0.1589[a]
U	5.8486[a]	0.1367[c]	0.1368[a]	0.1360[a]
T*Y	-0.6597[a]	1.3338	-0.2094[a]	-0.0224[a]
Constant	6.1195[a]	3.8531[c]	1.6403[a]	2.4785[a]
Hansen's J statistics	0.9174	1.3447	0.8869	0.8365
DWH Test statistics	5.3578[a]	8.6970[a]	8.0709[a]	6.7924[b]
Shape of EKC	N-shaped	N-shaped	N-shaped	N-shaped
Turnaround point(s)	a) 1.09 b) 2290.36	a) 1.43 b) 4600.57	a) 1.71 b) 6355.17	a) 2.78 b) 2207.39

a value at 1% significance level
b value at 5% significance level
c value at 10% significance level