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Renewable Energy, Water, and Environmental Degradation: A Global Panel Data Approach

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Abstract

Climate change and changing climatic patterns are posing a threat to the sustainability of life on earth. Climate change is attributed to the accumulation of greenhouse gas emissions (GHG) in the atmosphere representing environmental degradation. This study explores the links of renewable energy, water withdrawal, and economic growth with environmental degradation and provides empirical evidence using the panel data of 166 countries over the period 1990-2017. The study used panel data techniques and reported the results obtained from Pooled OLS, Random Effects, Fixed Effects estimations and 2 Stage Least Square(2SLS). The results support the role of renewable energy in environmental mitigation whereas water withdrawal contributes to emissions. Furthermore, results support the existence of the Environmental Kuznets Curve (EKC). Empirical evidence also suggests the positive role of solar, wind, geothermal and hydroelectricity in environmental improvement. The sensitivity analysis also confirms the robustness of empirical findings. The sensitivity analysis also indicates the validity of N-shaped EKC. The study provides useful insights into the role played by renewable energy in environmental mitigation and water withdrawal in increasing emissions which help to promote the consumption and production of renewable energy and increase its share in the energy mix for environmental mitigation.

Keywords: renewable energy consumption, water withdrawal, environmental degradation, carbon dioxide, urbanization.

1. Introduction

Exploring the causes of climate change has become a global research agenda. There is mounting scientific evidence that anthropogenic activities are responsible for climate change mainly caused by greenhouse gas emissions (GHGs). Over the last several decades, both developed and developing nations have extensively used fossil fuels to facilitate economic growth process and other development activities. As a result GHGs have increased in almost all regions of the world. “The highest emissions in history were recorded from 2000 to 2010” (IPCC, 2014). Consequently, the concentration of pollutants such as nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4) has increased by 20%, 40%, and 150%, respectively. The sectoral contribution to GHGs includes energy

(47%), industry (30%), transport (11%) and building (3%) sector, respectively (IPCC, 2014).

Thus, highest contribution to GHGs comes from energy sector. The concentration of GHGs in the atmosphere measures environmental degradation. Among GHGs, carbon dioxide is generally used as proxy of the environmental degradation (Balsalobre-Lorente et al., 2018; Ozokcu & Ozdemir, 2017; Majeed & Mumtaz, 2017; Majeed & Mazhar, 2019a). Globally, carbon dioxide emissions have been led by population and economic growth as both require intensive use of energy. The contribution of energy to environment, however, depends upon the type of energy sources. Non-renewable energy sources are mainly considered responsible for environmental degradation whereas energy extracted from renewable resources helps to improve the quality of environment.

There is an increasing interest in exploring technological advancement and cost-effectiveness of renewable energy options (solar, hydropower, wind and biomass) in mitigating environmental degradation. Renewable energy resources have the potential to meet the increasing demands of energy production without compromising environment and economic growth. It does not emit pollutants, it replaces pollutant generating nonrenewable technologies (Bilgili et al., 2016), it does not deplete unlike fossil fuels (Akella et al., 2009; Tsoutsos et al., 2005), and it creates spillover effects. In addition, thermal pollution can be avoided which is caused by conventional sources of energy production (Akella et al., 2009). Despite these merits, some studies suspect the environmental benefits of renewable energy. For example, Jebli & Youssef (2017) argue that combustible renewables and waste are not clean energy use. In effect, emissions can increase if **c**ombustible renewables and waste have major share in renewable energy sources.

Though theoretical literature largely considers renewable energy as favorable for quality of environment, yet empirical studies provide contentious results. One group of the empirical studies finds emissions reducing effect of increasing use of renewable energy (Sulaiman et al., 2013; Bilgili et al., 2016; Dogan & Ozturk, 2017; Ito, 2017; Balsalobre-Lorente et al., 2018; Kahia et al., 2019; Sharif et al., 2019), Another group of studies provides evidence of emission increasing effect of renewable energy (Apergis et al., 2010; Boluk & Mert, 2014; Jebli & Youssef, 2017). Some studies provide insignificant effect of renewable energy on emissions (Al-Mulali et al., 2015).

Along with renewable energy, water is another factor that affects the quality of environment. Water withdrawal is becoming a challenge as over exploitation of water sources lead to environmental degradation whereas sustainable withdrawals lead to a balance in the environment. As most of the countries around the globe are concerned about the environmental condition, therefore, it is imperative to focus on the role of water for environmental improvement. Water is one of the important sources of generating renewable energy, particularly hydroelectric power. Water scarcity and increasing water pollution have attracted the attention of researchers from all over the world. Water extraction requires energy which results in emissions. Wastewater management is another issue and if is not properly managed then it leads to contamination of groundwater and results in environmental degradation. Furthermore, it leads to eutrophication.

The 6th sustainable development goal stresses on "the availability of sustainable water and sanitation services for all". Water availability ensures the sustainability of the natural environment which provides educational, aesthetic and spiritual benefits among others. Furthermore, water availability ensures ecosystem sustainability which provides multiple services like groundwater recharge, stabilization of shores, food availability, tourism, and recreation along with job availability (UNESCO, 2009). The negative effect of water on the environment can be observed through energy consumption, soil respiration and discharge of wastewater in freshwater bodies. Water extraction requires energy. With economic and exponential population growth pressure on water, reservoirs are increasingly leading to increased withdrawals. Energy consumption for water withdrawal increases emissions.

Since environmental degradation has increasingly become a global challenge, addressing it requires global empirical approach. This research identifies two major forces that can help to fight against global environmental degradation. First, switching from non-renewable resources to renewable sources significantly improves the quality of environment in a panel of 166 countries over the period 1990-2017. In contrast, water withdrawal significantly degrades the quality of environment in a same panel of countries. Finally, EKC is also validated by this study.

The present study contributes into the literature on environmental degradation through a number of ways. First, the literature on environment and renewable energy is not conclusive as empirical evidence is largely based on country or regional specific evidence. This study uses global panel data analysis approach and provides more robust and conclusive results. Second, this study extends EKC framework for renewable energy as well as for water, which is largely ignored in the extant empirical literature. Third, this study segregates renewable energy according to the source of production. Fourth, this study provides a systematic analysis of theoretical approaches for environment-energy-water nexus unlike the previous literature which focuses more on empirical exercise. Fifth, this study resolves the issue of endogeneity using instrumental estimation approach, which is ignored by earlier studies. Sixth, this study also takes care of country specific fixed and Random effects to provide more robust results.

The current study tests the following hypothesis empirically: 1) Economic development and environmental degradation follows a nonlinear relationship where quality of environment degrades at lower level of economic development and begins to improve at higher level of economic development, 2) Renewable energy is positively associated with the quality of environment, and 3) The increasing withdrawal of freshwater is positively related with environmental quality.

By highlighting the role of renewable energy, water withdrawal and economic growth the study plays an important role in addressing the issue of climate change caused by environmental degradation. Trends of increasing environmental degradation can be reversed through the application of renewable energy in different sectors and decoupling economic growth from environmental degradation. Similarly, water-efficient technologies can ensure water availability and reduction in emissions caused higher level of water extraction.

The remaining study is structured as follows: Next Section incorporates the literature review. The methodological framework is explained in Section 3. Section 4 is based on the results and discussion. Section 5 provides conclusion and policy implications.

2. Literature Review

In the present era, climate change has become a major sustainability concern all over the world. Climate change represents a change in temperature, precipitation, and evaporation, which are changing because of increasing environmental degradation caused by anthropogenic activities (IPCC, 2014; Stern, 2006). Anthropogenic activities refer to the human activities causing pollution (World Bank, 2018; IPCC, 2014).

Climate change results in the melting of permafrost (IPCC, 2014) which releases huge quantities of methane in the atmosphere leading to global warming (Stern, 2006). Moreover, climate change affects water resources resulting in increased frequency of floods, droughts and decreased river flows (ADB, 2016). In this background, this section provides theoretical foundations and empirical evidence related to changes in environmental quality as a result of changes in growth, type of energy and water withdrawal.

The theoretical foundations have been drawn from the following theories: EKC theory, ecological modernization theory, environmental transition theory, Himalayan environmental degradation theory, social choice theory, and the value belief norm (VBN) theory. The EKC theory suggests that the quality of environment is compromised at lower level of economic development while societies follow strict checks and balances on the quality of environment at higher level of economic development.

The empirical validity of EKC has been extensively studied, but the evidence is mixed. The studies of Grossman & Krueger (1991), Holtz-Eakin & Selden (1995), Farhani et al. (2014) and Majeed (2018) supported inverted U-shape relationship whereas the studies of Ozokcu & Ozdemir (2017) and Balsalobre-Lorente et al. (2018) found N-shaped relationship. In contrast, Apergis et al. (2010), and Kahia et al. (2019) did not confirm the validity of EKC as their results documented a positive and linear effect of growth on emissions.

The ecological modernization theory was founded in 1980s by a group of scholars at Free University. It evolved over time. Earlier contributions towards this theory focused more on technological innovations for environmental reforms. From late 1980s to mid-1990s, this theory emphasized a more balanced role of states and markets in ecological transformation (Weale, 1992). Moreover, this theory asserts that institutional and cultural dynamics need to be focused for ecological reforms (Cohen, 1997). From the mid-1990s the scope of ecological modernization theory extended theoretically and geographically to incorporate studies on the ecological transformation of consumption and ecological modernization in non-European countries.

The transformations in ecological modernization theory can be grouped into five clusters: 1) Science and technology cause as well as offer the solutions of environmental problems. 2) Market dynamics and economic agents can play significant role in ecological reforms and restructuring. 3) Political modernization in terms of more flexible, decentralized and consensual types of governance structure emerges to support environmental regulations. 4) Social modernization in terms of modern social movements emerges to support the environmental reforms by involving in private and public decision making institutions. 5) Discursive practices are diminished and new ideologies emerged that focus more on quality of environment.

Likewise, environmental transition theory implies that when economies transit from traditional economy to industrial economy demand for energy consumption and urban infrastructure increases, thereby compromising the quality of environment. However, when economies become wealthier they improve their relationship with the environment by using clean technologies, following stricter environmental regulations and following structural reforms.

Himalayan theory of environmental degradation considers anthropogenic activities as the main cause of environmental degradation. Anthropogenic activities such as land clearance and deforestation in hilly areas result in floods and concentration of pollutants in the atmosphere. Farmers living in the mountains clear off the land to increase output which leads to deforestation on the hills and causes floods in the plains. Himalayan theory predicts that the activities of farmers living on the mountains exacerbate environmental problems and destruct civilization.

Social choice theory which incorporates welfare economics and voting theory emphasizes on "collective choices, preference judgment and welfare" as compared to individual preferences. Social choice theory can be accorded as demanding sustainability of environment at global level. The value belief norm (VBN) theory of environmentalism implies that personal norms and pro-environmental beliefs influence environmental behavior. When people endorse biospheric values, they feel more responsible for the problems caused by anthropogenic activities and pro-environmental behavior is promoted. In contrast, the more people endorse hedonic values, the less they feel responsible for the environmental problems (Stern, 2000).

2.1 Non-Renewable Energy and Environment

Energy consumption is one of the important factors that influence quality of environment. The demand of energy is generally fulfilled by non-renewable energy. The use of non-renewable energy, however, has negative effects on environmental degradation. The energy required to support development results in emissions. As energy production is based on fossil fuels which are rich in carbon there usage leads to release of carbon in the air causing environmental degradation. The strength of effects also depends upon how energy is extracted and processed, how it is used and how it is consumed. The use of energy from non-renewable sources affects the environment in following ways. First, non-renewable sources of energy emit greenhouse gas emissions. Among different type of non-renewable fuels, coal is referred as the worst emitter of CO_2 emissions while natural gas produces relatively less CO_2 emissions. However, natural gas cannot be considered as favorable energy use because it's drilling and extracting from wells produces methane which is more storing for heating trap as compared to CO_2 emissions.

Second, non-renewable energy sources a variety of pollutants. For instance, coal-fired plants are the source of mercury emissions. When the mercury is emitted into the air it is deposited on the ground or in water. It can accumulate in organism of species that inhabit the area and finally passed through the food chain. Consequently it has profound effects on the loss of bio diversity as well as causes real risks for humans. The combustion of fossil fuels also emits other pollutants like Sulphur dioxide, nitrogen oxides and particulate matter.

Third mechanism works through "acid rain and water pollution". Sulphur and other chemicals as a result of industrial processes remain suspended in the air and turn the rain mildly acid. Acid rain is dangerous for machinery and also disrupts local ecosystems. It enhances the acidity of lakes and streams which is very harmful for wild life, fish and humans. It also damages trees, thereby weakening forest ecosystem. The use of fossil fuels also creates "thermal pollution". Fossil fuel and nuclear power plants require water to run and cool the plant. When they release heated water back into the environment, its temperature is changed and quality is degraded.

Fourth mechanism works through "land pollution and waste generation". The extraction of non-renewable resources and the disposal of the waste they generate also affect the environment. For example, a huge volume of excess rock or soil as a result of mining is dumped into the nearby places, thereby affecting ecosystem. The quality of land mined is also degraded. Fifth mechanism works through "oil spills and other accident". Oil spills are enormously harmful to neighboring shores and ecosystems.

The empirical literature confirms the positive impact of energy use on emissions. The study of Alam et al. (2007), for Pakistan over the period 1971 to 2005, revealed a positive impact of energy intensity on CO_2 emissions. Similarly, for a panel of 8 MENA countries from 1975 to 2014, Gorus & Aydin (2019) also support positive effect of energy consumption on environmental degradation. In addition the studies of developed economies also support increased level of emissions caused by energy consumption. The study of Kasman & Duman (2015) showed a positive effect of energy consumption on environmental degradation for candidate and new Europe union member countries over the period 1992-2010. The study of Dogan et al. (2017) also showed a positive effect of energy consumption on environmental degradation for OECD countries. The results of Ozokcu & Ozdemir (2017) for a panel of high income and emerging economies are in line with the literature of energy-environment nexus. In a recent study, Majeed & Mazhar (2019b) also provide robust evidence of the positive effect of energy consumption on environmental degradation using a global panel data set of 131 countries from 1971 to 2017. The country specific, and region specific (either developed or developing) evidence highlight the role of energy in increasing emissions. Thus there is consensus in the literature on the positive impact of energy on emissions.

2.2 Renewable Energy and Environment

Given the environmental problems of non-renewable energy, policy makers are increasingly paying attention to non-renewable energy sources**.** The literature of renewable energy documents various mechanisms through which renewable energy helps to improve the quality of the environment. First, renewable energy does not emit pollutants and therefore quality of environment is not deteriorated. Second, renewable energy lowers environmental degradation because of the "substitution effect". That is, renewable energy is substituted with fossil fuels and the prospective emissions of fossil fuels are diminished (Bilgili et al., 2016). Third, renewable energy does not deplete unlike fossil fuels (Akella et al., 2009; Tsoutsos et al., 2005) and, therefore, does not burden the environment by freeing the resources from extraction and mining activities. Fourth, renewable energy improves the quality of environment by generating dynamic effects through economies of scale and spillover effects. According to technological transfer theory, “horizontal” or international perspective of technology transfer “enable developing countries to acquire, adapt, deploy and diffuse renewable energy technologies from overseas and further innovate as a result of the capabilities acquired through the technology transfer process”. Fifth, by using renewable energy sources for energy production thermal pollution can be avoided which is caused by conventional sources of energy production (Akella et al., 2009).

In contrast, some studies also argue that renewable energy can also negatively affect the quality of environment. Combustible renewables and waste are not clean energy use. If they have major share in renewable energy sources then emissions can increase (Jebli and Youssef, 2017). “Renewable energy sources, such as biofuels, solar, wind and geothermal energy, require substantial amount of water and land”. Given the limited availability of land and water resources, renewable energy resources will increase ecological footprint, thereby degrading the environment (Al-Mulali et al., 2016). Using a sample of 58 countries from 1980 to 2009, Al-Mulali et al., (2016) confirm that renewable energy increases ecological footprint by increasing the inefficiency of land and water use and therefore degrade the environment.

Another issue with renewable energy is that nature of its output is “intermittent” and it also lacks of suitable storage technology. For these reasons, a break-up power source is needed for large peak electricity production, which is generally supported by fossil fuel (Heal, 2009; Forsberg, 2009). It is also argued that the mitigation impact of renewable energy is observed after a threshold point. Chiu & Chang (2009) provide evidence to favor this argument. They argued that the mitigating impact of renewable energy on CO2 emissions begins when 8.39 percent of total energy supply is contributed by renewable energy production.

With growing demand for energy to support the growth of both developed and developing countries, the sustainable availability of energy is increasingly becoming global concern. In particular, sustainable and secure energy is becoming global because of the volatile prices of fossil fuels and depleting energy sources. In this regard reducing dependence on imports of fossil fuels for energy production and harnessing the potential of domestic renewable energy alternatives offer promising solutions.

Renewable energy sources “such as solar, wind, geothermal, biomass and small hydropower plant” ensure the sustainability of energy and are inexhaustible, unlike fossil fuels which deplete (Tsoutsos et al., 2005). Renewable energy ensures energy security and sustainability (Prandecki, 2014). Among renewables, solar energy is extensively available and has the potential to meet the growing demand for energy and to slow down climate change as it does not produce emissions. Solar energy is the cleanest form of energy that has the least environmental impact. The solar energy capacity of the world has increased. Solar energy is not vulnerable to weather patterns. Solar energy does not lead to any gaseous emissions to air or generate liquid and solid waste thus improving the environment (Devabhaktuni et al., 2013; Bhattacharyya, 2011; Solangi et al., 2011). In addition renewable energy has spillover effects. Because of decentralized nature of renewable energy it increases job opportunities and can easily be applied with low maintenance cost which leads to spillover effects (IRENA, 2019). Dependence on imports of fossil fuels affects trade balance and leads to macro-economic instability whereas harnessing of renewable energy reduces the vulnerability of the economy to external economic shocks. Renewable energy increases employment opportunities because of its decentralized nature. Off-grid solar units can be installed in rural communities and far-flung areas, which lack electrification. Off grid units have ensured access to energy which improves businesses and employment opportunities (IRENA, 2016).

Different studies have been under taken to understand the impact of renewable energy on the quality of environment. The study of Sulaiman et al., (2013) highlighted the importance of renewable energy sources in mitigating environmental degradation in the case of Malaysia over the period 1980-2009. Similarly, the study of Belaid & Youseef (2017) found out the negative effect of renewable energy on emissions for Algeria from 1980 to 2012. Dogan & Ozturk (2017) highlighted the role of renewable energy in mitigating emissions for the USA from 1980 to 2014. However, Al-Mulali et al., (2015) reported insignificant effect of renewable energy consumption on emissions for Vietnam over the period 1981-2011.

In the case of developed economies Ito (2017), in 25 African countries Zoundi (2017) and in 12 MENA countries Kahia et al. (2019) highlighted the role of renewable energy in mitigating emissions. In contrast to these results, the findings of Farhani & Shahbaz (2014) supported the positive effect of renewable and non-renewable energy consumption on CO_2 emissions in 10 MENA countries over the period 1980-2009. Jebli and Youssef (2017) also supported the positive effect of renewable energy on emissions by examining the dynamic causal links of renewable energy and emissions for a panel of five North African countries over the period 1980-2011.

In the case of developed economies the study of Bilgili et al. (2016), on a panel of OECD countries from 1977 to 2010, documented negative effect of renewable energy on carbon emissions. Similarly Balsalobre-Lorente et al. (2018) examined the relationship between renewable energy and carbon dioxide emissions for Germany, France, Italy, the United Kingdom, and Spain for the period 1985-2016. Their analysis showed that renewable electricity consumption, energy innovation, and abundance of natural resources improve environment. However, in contrast to above findings Boluk & Mert (2014) indicated a positive effect of renewable energy consumption on emissions of GHGs in a panel of EU countries for the period of 1990-2008.

Using a sample of 19 developed and developing countries from 1984 to 2007, Apergis et al. (2010), showed a positive effect of renewable energy consumption on carbon emissions. Whereas Sharif et al. (2019) reported a negative impact of renewable energy consumption on emissions of 74 nations using second generation panel data Econometrics over the period 1990-2015.

As energy is the engine of growth, this energy production can improve and degrade the environment based on the source used for energy generation. Energy generated from conventional sources (fossil fuels) increases emissions while the use of renewable energy resources such as wind, solar, hydropower, biomass, biogas, and geothermal for energy generation improves the environment. The positive effect of non-renewable energy consumption on emissions is extensively documented in the literature. However, the effect of renewable energy on environment is relatively less explored. Moreover, the available evidence on renewable energy and environment are not conclusive. Generally, studies find negative effect of renewable energy on emissions (Sulaiman et al., 2013; Bilgili et al., 2016; Belaid & Youseef, 2017; Dogan & Ozturk, 2017; Ito, 2017; Zoundi, 2017; Balsalobre-Lorente et al., 2018; Kahia et al., 2019; Sharif et al., 2019). A small body of the literature finds positive effect of renewable energy on emissions (Apergis et al., 2010; Farhani & Shahbaz, 2014; Boluk & Mert, 2014, Jebli and Youssef, 2017). Few studies also report insignificant effect of renewable energy on emissions (Al-Mulali et al., 2015).

2.3 Water-Energy-Environment Nexus

Environmental degradation led climate change is affecting economies around the globe (Majeed and Mumtaz, 2017). Whereas the role of energy and economic growth is extensively studied, the role of water has not been received due attention. Sustainability of water resources has become the prime objective of all economies. Water affects environment through multiple ways. Since water is integrated with all spheres of life, its effects on environment are diverse and complicated.

Water availability contributes to environmental sustainability, as water is needed for the protection of ecosystems. Water availability can be ensured through water related climate regulation, purification of wastewater (UNESCO, 2009). Water availability ensures the sustainability of the natural environment which provides educational, aesthetic and spiritual benefits among others. Furthermore, water availability ensures ecosystem sustainability which provides multiple services like groundwater recharge, stabilization of shores, food availability, tourism, and recreation along with job availability (UNESCO, 2009).

The negative effect of water on the environment can be observed through energy consumption, soil respiration and discharge of wastewater in freshwater bodies. Water extraction requires energy. With economic and exponential population growth pressure on water, reservoirs are increasingly leading to increased withdrawals. Energy consumption for water withdrawal increases emissions.

Lofman et al. (2002) highlighted the importance of energy for water extraction, conveyance, and delivery to the end-user. This whole process requires energy. Not only the extraction of water but falling water table and saltwater intrusion also lead to contamination of water and need treatment before use. Thus the whole process is energy-intensive which leads to environmental degradation. The work of Wang et al. (2012) highlighted the effect of groundwater abstraction on GHGs in China. Their results suggest that increased use of energy for pumping groundwater leads to GHG emissions. Similarly, Rafindadi et al. (2014) concluded positive relationship among air pollution, water resources, non- renewable energy and energy use for 10 Asia-Pacific countries over the period 1975-2012.

Another mechanism through which water withdrawal affects the environment is "soil respiration". Water withdrawal affects the ecosystem which affects the environment through soil moisture. Soil moisture has the capacity to absorb carbon but when water extraction is more than recharge it leads to decrease in soil moisture. Decrease in soil moisture increases the amount of carbon dioxide and methane released in the atmosphere, which was stored in the soil. The lack of water in the soil in form of moisture reduces its ability to absorb carbon. Thus, when groundwater abstraction increases it leads to a decrease in soil moisture causing release of CO_2 in the atmosphere causing environmental degradation (UNESCO, 2015; UNESCO, 2009). Extensive groundwater extraction drops water table and requires more energy to pump water for domestic and irrigation purposes. Excessive extraction of water causes degradation of groundwater quality because of saltwater intrusion and also decreases surface water which possesses the capacity to absorb carbon dioxide, thus resulting in environmental degradation (Fienen & Arshad, 2016).

Economic growth is putting great pressure on water resources by increasing water scarcity. In addition, groundwater abstraction is causing an increase in emissions. Water quality and quantity are declining due to drying of rivers, aquifers, groundwater basins, eutrophication, nutrient loss of rivers all this has a negative effect on the ecosystem and environment (UNESCO, 2009; UNESCO, 2017). Furthermore, when wastewater is dumped in the freshwater bodies it cannot be used directly and need treatment. Treatment of wastewater consumes energy and leads to emissions (Zakkour et al., 2002; UNESCO, 2017).

It can be concluded from the above discussion that the literature shows a consensus regarding the impact of non-renewable energy on emissions while the evidence on the effects of renewable energy on emissions is contradictory. Therefore, the current study occupies a special position in the literature by contributing to the debate of energy-environment nexus, as the availability of renewable energy sources is not constrained like fossil fuel which depletes and degrade the environment. Moreover, renewable energy ensures energy security as well.

Along with renewable energy, water is an important source for life and its sustainability; therefore, the current study explored the link of water with the environment which is ignored in the literature. The effect of renewable energy and water on the environment in a same model is missing and only limited to country-specific and regions specific findings which cannot be generalized on a global level. Therefore the current study bridges this gap in energy-water-environment nexus. Furthermore, the study segregates renewable energy according to the source of production. Although, the literature on growth-environment nexus is well established still the evidence is mixed, this study also investigates the EKC. The study adds to the green economy literature by empirically analyzing the effect of renewable energy and water withdrawal on emissions.

3. Methodology

3.1 *Theoretical Framework*

Theoretical frame work of this study is based on an extended version of Environmental Kuznets curve (EKC). According to EKC, as an economy develops production level and carbon emissions increase together. However, at a higher level of economic development input mix changes because of the availability of clean technologies such as renewable energy, thereby reducing carbon emissions (Grossman & Kruger, 1991). The baseline equation is based on the model used by Holtz-Eakin & Selden (1995), Chandran & Tang (2013), Kasman & Duman (2015), Bilgili et al. (2016) and Majeed (2018).

$$(\text{Environmental degradation})_{it} = f(\text{GDP}, \text{GDP}^2)_{it} \qquad (1)$$

This study revisits EKC incorporating the role of renewable energy in explaining environmental degradation. The use of renewable energy leads to environmental improvement as it is the cleanest form of energy and does not lead to emissions and resource depletion. Solar and wind energy are the cleanest form of energy. Unlike fossil fuels, renewable energy is inexhaustible. The role played by renewable energy in mitigating environmental degradation has been explored by Bilgili et al. (2016) and Zoundi (2017) among others.

This study also incorporates the role of water withdrawal in EKC framework, which is largely ignored in the earlier studies. Water plays an important role in the reduction of emissions. Sustainable withdrawal of water leads to fewer emissions of CO_2, as more water withdrawal leads to less soil moisture and decreased capacity of soil to absorb carbon dioxide. Plants also play an important role in absorbing CO_2 and releasing Oxygen. With fewer water withdrawals less energy will be used for extraction and emissions can be controlled. Water is a basic natural resource which has its role in all sectors of the economy. Proper management and utilization of water resources can lead to overcoming the problem of water shortage in water-scarce regions whereas mismanagement of water resources and overexploitation has led to severe environmental consequences.

With exponential population growth, and poor rural conditions rural urban migration takes place. The reasons behind rural urban migration are the provision of facilities such as education, job and medical among others. This rural-urban migration puts pressure on limited resources available in urban areas amplifying overexploitation and environmental degradation. Urbanization puts pressure on water resources to meet the demands of an increasing population. Therefore, urbanization coupled with rapidly increasing population leads to overexploitation of water resources for drinking, domestic, sanitation, and hygiene. In such a scenario, demand for food, transportation, and energy increases, thereby overburdening the environment.

Most of the sectors in the economy need water for their operation among these sectors the most important are agriculture, industry, and energy. To ensure food security, globally 70% of extracted water is used for agriculture. The runoff from agriculture is contaminated because of the application of pesticides and chemicals on the crop to increase per acre yield from agriculture. Also because of inefficient irrigation practices, this unutilized water when mixed with streams and absorbed in natural aquifers leads to contamination of water. Thus contaminated water causes environmental degradation. Therefore to control for the effect of land under agriculture on emissions, agriculture land is incorporated in the model. Jabeli & Youssef (2017) found that agriculture value-added reduces CO_2 emissions. Therefore, the model can be specified as below

$$\text{Enivronmntal Degradation}_{\text{it}} = \text{f(GDP, GDP}^2\text{, Renewable Energy, Water withdrawl, Urbanization, Agriculture)}_{\text{it}} \; (2)$$

3.2 Empirical Model and Variable Description

Renewable energy and water can play an important role in sustainable development by improving the environment. To assess the effect of renewable energy and water withdrawal on environmental degradation, the following model has been constructed,

$$Co2_{it} = \propto_0 + \propto_1 y_{it} + \propto_2 {y^2}_{it} + \propto_3 rec_{it} + \propto_4 aft_{it} + \propto_5 up_{it} + \propto_6 als_{it} + u_i + v_t + \varepsilon_{it} \; (3)$$

where "CO_2 is carbon dioxide emissions (metric tons per capita)" used to represent environmental degradation, y is "GDP per capita (constant 2010 US$)" used for economic growth, Y^2 is GDP per capita square, rec is "renewable energy consumption (% of total final energy consumption)" as a proxy of energy, "aft is annual freshwater withdrawals, total (billion cubic meters per capita)", up is urban population used for urbanization (annual %), als is agriculture land (square kilometer), $\propto_0$ and ε_{it} are intercept and error term while u_i represent unobserved country specific characteristics and v_t is used for time fixed effects respectively.

Similarly to explore the effect of different renewable energy sources on emissions, renewable energy has been segregated according to the source used to produce renewable electricity. Equations used to estimate the relationship are

$$Co2_{it} = \propto_0 + \propto_1 y_{it} + \propto_2 {y^2}_{it} + \propto_3 eler_{it} + \propto_4 aft_{it} + \propto_5 up_{it} + \propto_6 als_{it} + u_i + v_t + \varepsilon_{it} \; (4)$$

$$Co2_{it} = \propto_0 + \propto_1 y_{it} + \propto_2 {y^2}_{it} + \propto_3 eleh_{it} + \propto_4 aft_{it} + \propto_5 up_{it} + \propto_6 als_{it} + u_i + v_t + \varepsilon_{it} \; (5)$$

$$Co2_{it} = \propto_0 + \propto_1 y_{it} + \propto_2 {y^2}_{it} + \propto_3 eler_{it} + \propto_4 aft_{it} + \propto_5 up_{it} + \propto_6 als_{it} + \propto_7 eleh_{it} + u_i + v_t + \varepsilon_{it} \; (6)$$

To capture the effect of solar, wind, biogas, biofuel, tide and geothermal, electricity produced from renewables (eler) KWH per capita is used as a proxy whereas to represent electricity produced from hydropower plants (eleh) % of total electricity has been used. Equation 6 analyzes the combined effect of hydroelectricity and electricity from renewables (solar, wind, tides, biomass, biofuels and geothermal).

Table 1: Variable Description

Variables	Definition of Variable	Measurement	Source
Dependent Variable			
CO_2 Emissions	"Carbon dioxide emissions are those stemming from the burning of fossil fuels and manufacture of cement and result of anthropogenic activities."	Metric tons per capita	**WDI, 2018**
Independent Variables (Focused Variables)			
Renewable Energy Consumption	"Renewable energy consumption is the share of renewable energy in total final energy consumption."	% of total final energy consumption	**WDI, 2018**
Electricity Production from Renewable Sources	"Electricity production from renewable sources, excluding hydroelectricity, includes geothermal, solar, tides, wind, biomass, and biofuels."	Kwh per capita	**WDI, 2018**
Hydroelectricity	"Sources of electricity refer to the inputs used to generate electricity. Hydropower refers to electricity produced by hydroelectric power plants."	% of total	**WDI, 2018**
Annual Freshwater Withdrawals	"Annual freshwater withdrawals refer to total water withdrawals which include withdrawals for agriculture, domestic, municipal and public use. It does not account for evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source."	Billion cubic meters per capita	**WDI, 2018**
Independent Variables (Control Variables)			
GDP Per Capita	"GDP per capita is gross domestic product divided by midyear population. It excludes asset depreciation and depletion and depletion and degradation of natural resources."	Constant 2010 US$	**WDI, 2018**
GDP Per Capita Square	"GDP per capita square is the square of GDP per capita (constant 2010 US$)."	Constant 2010 US$	**WDI, 2018**
Urban Population	"Urban population refers to people living in urban areas (growth rate)."	Annual %	**WDI, 2018**
Agriculture Land	"Agriculture land refers to the share of land area that is arable, under permanent crops and permanent pastures."	Sq.km	**WDI, 2018**

Other Variables			
Trade	"Trade is the sum of exports and imports of goods and services and is taken as a share of gross domestic product."	% of GDP	**WDI, 2018**
Inflation	"Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole."	Annual %	**WDI, 2018**
Foreign Direct Investment Net Inflows	"It shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP."	% of GDP	**WDI, 2018**
Population Density	"Population density is midyear population divided by land area in square kilometers. It counts all residents regardless of legal status or citizenship except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin."	People per square kilometer of land area	**WDI, 2018**

As EKC suggests a non-linear (quadratic) relationship between income and pollutant emissions, therefore, the expected sign of $\propto_1$ is positive and $\propto_2$ is negative. Renewable energy is expected to decrease emissions, therefore, the expected sign of $\propto_3$ is negative ($\propto_3$ and $\propto_7$ are expected to appear with a negative sign in all equations. As water withdrawal requires energy, therefore, it leads to increased emissions, so $\propto_4$ is expected to be positive. Urbanization leads to increased demand for transportation and puts pressure on resources therefore, $\propto_5$ is expected to be positive. Similarly land under agriculture leads to contamination of ground water and water extraction for agriculture leads to more emissions therefore, $\propto_6$ is expected to be positive.

3.3 Data Sources and Techniques

The data has been extracted from the World Bank (2018). The study has used panel data of 166 countries over the period 1990-2017. The selection of the sample size and time span is based on the availability of data. All the variables have been transformed into a natural logarithmic as it provides efficient and consistent results and controls heteroscedasticity (Al-Mulali et al., 2016).

The study reported results of Pooled OLS, Random Effects, Fixed Effects and 2 Stage Least Squares (2SLS). The decision of methodology is based on certain characteristics of the models. As Pooled estimation does not account for country specific and time specific effects therefore to capture country specific characteristics Random and Fixed effects are incorporated. Random effects can provide meaningful results if no correlation exists between country specific characteristics (which are taken as random) and regressors (corr ui & Xi =0) whereas Fixed effects assume correlation of country specific characteristics with regressors to consider for such correlation Fixed effects are incorporated.

Furthermore, as Fixed effects do not account for time invariant characteristics and endogeneity, 2SLS is incorporated to overcome such issues. Because of heteroscedasticity Driscoll and Kray (DK) estimators are reported (Koengkan, 2018). Breusch Pegan Langrange multiplier test is used to choose between Pooled and Random effects models. In the next step the choice between Random and Fixed effects is made on the bases of Hausman test. The validity of instruments is tested with the help of Sargan and Basman Score.

4. Results and Discussion

4.1 Pooled OLS Results

Table 2 reports the results obtained using Pooled OLS. All columns (1-4) of Table 2 indicate that EKC is validated in all regressions. The sign of parameter estimate on GDP per capita is positive and significant indicating that 1% increase in GDP per capita is associated with 2.764% increase in CO_2 emissions. Whereas the sign of parameter estimate on GDP per capita square is negative and significant highlighting that 1% increase in GDP per capita square is associated with 0.121% decline in CO_2 emissions. Thus the results are consistent with EKC, which emphasizes that initial level of development is associated with environmental degradation due to use of old technologies (technological effect) and production of primary products (composition effect) and lack of research and development. However after achieving a threshold level of income environmental degradation tends to decrease because of sectoral shifts and technological advancements (Ozturk & Acaravci, 2013; Ang, 2007). These findings are consistent with other studies such as Grossman & Krueger (1991), Holtz-Eakin & Selden (1995), Ang (2007), and Sharif et al. (2019).

Column 1 presents the result of renewable energy consumption whereas Columns 2-4 show the results of electricity produced from renewables (solar, wind, geothermal, timed, biofuel and biogas) and hydroelectricity. The negative and significant coefficient of renewable energy shows that one percent incline in renewable energy consumption decreases carbon emissions by 0.245 percentage points. This finding is consistent with ecological modernization theory, which emphasizes on technological innovations to enhance the quality of environment. The results support the environmental transition theory, social choice theory and clean development mechanism (CDM). Renewable energy contributes to clean environment because of substitution effect as it replaces conventional technologies which rely on fossil fuels (Bilgili et al., 2016). In addition, it does not burden the environment as it is inexhaustible (Tsoutsos et al., 2005) and sustainable (Akella et al., 2009) as compared to non-renewable energy. It ensures energy security (Prandecki, 2014; Devabhaktuni et al., 2013; Tsoutsos et al., 2005) and possesses economies of scale and spillover effects because of easy application and lower maintenance costs. The results are consistent with the studies of Sharif et al., (2019) and Koengkan (2018) who highlighted the role of renewable energy consumption in reduction of carbon emissions however, the results are contradictory to the findings of Apergis et al. (2010) and Farhani & Shahbaz (2014) who reported positive effect of renewable energy on emissions. The reason behind this difference is the nature of this study which is based on global panel data and incorporates most important factors effecting environmental degradation.

The coefficient of water withdrawal per cpaita is positive and significant indicating that 1 percent increase in water withdrawal per capita will increase carbon dioxide emissions by 0.0468 percent. Emissions increase because groundwater extraction requires energy generated from fossil fuels (Fienen & Arshad, 2016, UNESCO, 2003). Energy is not the only factor related to environmental degradation because of water extraction, salt water intrusion (Fienen & Arshad, 2016, Lofman et al., 2002) and anthropogenic activities (UNESCO, 2015) like agriculture, industry, and urbanization also leads to groundwater contamination (Foster et al., 2002) causing increased emissions. The contaminated water needs treatment before use, which further increases emissions (Zakkour et al., 2002; UNESCO, 2017). Increased withdrawals lead to decrease in soil moisture causing release of CO_2 in the atmosphere another reason behind environmental degradation (UNESCO, 2015; UNESCO, 2009). The results are consistent with existing studies of Rafindadi et al. (2014) and Wang et al. (2012) who documented the positive effect of water withdrawal on emission.

The coefficients of urbanization and agricultural land, in Column 1, are positive and significant implying that with an increase in the urban population and agricultural land, CO_2 emissions will increase by 0.229 and 0.0551% percentage points, respectively. Urbanization is an important factor contributing to the increase in CO_2 emissions, because of the increase in demand for energy and transportation (IPCC, 2014). The findings are supported with the literature of Poumanyvong & Kaneko (2010) and Alam et al., (2007) and in contrast with the findings of Rauf et al., (2019). The difference in the results is because of the sample size. The coefficient of agriculture land highlights that with an increase in land under agriculture CO_2 emissions will increase. The results are consistent with the finding of Rauf et al., (2018). The increase in CO_2 emissions from the increase in land under agriculture is because of the high use of pesticides and fertilizers to increase productivity and to meet the increasing demands of livestock (IPCC, 2014).

Columns 2-4 highlight the impact of electricity produced from renewables, hydroelectricity and combined effect of electricity production from renewables on carbon emissions. The negative and significant results of renewable energy highlight its importance in mitigating environmental degradation. High R^2 indicates the explanatory power of the model as 87% of the variation in the environmental degradation is explained by the explanatory variables. F-statistics indicates that all independent variable add to the explanatory power of the model. To deal with the heteroscedasticity problem Driscoll & Kray standard errors are reported (Koengkan, 2018).

Table 2: Pooled OLS Results of Renewable Energy and Water on CO_2

	1	**2**	**3**	**4**
Variables	**lCO_2**	**lCO_2**	**lCO_2**	**lCO_2**
GDP per capita	2.764***	2.907***	2.441***	2.345***
	(0.209)	(0.352)	(0.355)	(0.380)
GDP per capita	-0.121***	-0.121***	-0.104***	-0.0902***
Square	(0.0106)	(0.0196)	(0.0187)	(0.0204)
Renewable energy	-0.254***			
Consumption	(0.0171)			
Electricity from		-0.0869***		-0.0743***
Renewables		(0.0102)		(0.00978)
Hydroelectricity			-0.128***	-0.112***
			(0.0120)	(0.0124)
Water withdrawal	0.0468**	0.0983***	0.0727**	0.0571***
Per capita	(0.0222)	(0.0223)	(0.0272)	(0.0163)
Urbanization	0.229*	0.146	0.242	0.0123
	(0.113)	(0.0925)	(0.163)	(0.138)
Agriculture land	0.0551***	0.0211	0.0634***	0.0799***
	(0.00737)	(0.0139)	(0.0162)	(0.0147)
Constant	-13.83***	-14.00***	-12.40***	-12.00***
	(1.030)	(1.765)	(1.327)	(1.452)
Observations	440	272	399	259
R^2	0.874	0.781	0.801	0.821
F	636.54***	198.49***	281.66***	1070.45***
Driscoll &Kray standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				
Stata command xtssc is used				

4.2 Random Effects Results

Pooled OLS does not deal with country specific and temporal effects, therefore we Random Effects approach of estimation is used. Table 3 reports the results obtained from Random Effects estimation which accounts for country specific characteristics as random. The results indicate that all measures of renewable energy contribute to emissions reduction and water withdrawal leads to increased emissions. All the results are significant and possess correct sign. To control for heteroscedasticity Driscoll Kray standard errors are reported in parenthesis (Koengkan, 2018). Breusch-Pegan LM test is applied to choose between Pooled and Random effects. The null of no Random effects

(Pooled estimation is the proper technique) is rejected at 1% level of significance in all columns (1-4) indicating the presence of Random effects in the model.

Table 3: Random Effects Results of Renewable Energy and Water on CO_2

	1	**2**	**3**	**4**
Variables	**lCO_2**	**lCO_2**	**lCO_2**	**lCO_2**
GDP per capita	1.292^{***}	2.303^{***}	1.806^{***}	2.137^{***}
	(0.372)	(0.543)	(0.153)	(0.473)
GDP per capita square	-0.0445^{**}	-0.0933^{***}	-0.0790^{***}	-0.0838^{***}
	(0.0185)	(0.0279)	(0.00720)	(0.0246)
Renewable energy	-0.217^{***}			
consumption	(0.0281)			
Electricity from		-0.0523^{***}		-0.0551^{***}
Renewables		(0.00819)		(0.00624)
Hydroelectricity			-0.109^{***}	-0.0813^{**}
			(0.0354)	(0.0342)
Water withdrawal per	0.0775^{**}	0.0913^{*}	0.138^{**}	0.0648^{*}
Capita	(0.0366)	(0.0515)	(0.0504)	(0.0339)
Urbanization	0.502^{**}	0.323	0.337^{*}	0.264
	(0.212)	(0.193)	(0.181)	(0.156)
Agriculture land	0.00405	0.0105	-0.00139	0.0671^{***}
	(0.0219)	(0.0315)	(0.0443)	(0.0210)
Constant	-7.279^{***}	-11.72^{***}	-7.692^{***}	-11.59^{***}
	(1.393)	(2.652)	(1.101)	(2.171)
Observations	440	272	399	259
R^2	0.8607	0.7744	0.7817	0.8134
Wald chi 2	769.53^{***}	2050.41^{***}	1202.83^{***}	1778.31^{***}
BP LM Test	0.000	0.000	0.000	0.000
Driscoll and Kray Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

4.3 Fixed Effects Results

Random effects are based on the assumption of no correlation between country-specific characteristics (which are taken as random) with the regressors (correlation Xi and ui=0). In contrast, fixed effects assume correlation of country-specific characteristics with regressors. Table 4 presents the results obtained from fixed effects estimation. All the coefficients hold expected signs and are significant. Renewable energy improves environment whereas water extraction contributes to CO_2 emissions. EKC is also validated.

For model selection, the Hausman test is applied which tests for the correlation of country-specific characteristics with the independent variables and assumes that no correlation exists indicating that Random effects are better than Fixed effects. However the results of Hausman test for current study support fixed effects in all specifications (1-4) as p-value is less than 5%. These results suggest that country-specific characteristics are important in influencing the links among the variables under consideration. The results of redundant fixed effects LR ratio and time fixed effects are also reported which indicate that cross sectional time invariant and temporal effects are playing important role in explaining the results.

Table 4: Fixed Effects Results of Renewable Energy and Water on CO_2

	1	2	3	4
Variables	**lco2m**	**lco2m**	**lco2m**	**lco2m**
GDP per capita	0.742***	2.055***	1.573***	1.956***
	(0.199)	(0.447)	(0.235)	(0.384)
GDP per capita square	-0.0225*	-0.0876***	-0.0745***	-0.0842***
	(0.0118)	(0.0228)	(0.0146)	(0.0186)
Renewable energy	-0.164***			
	(0.0326)			
Electricity from		-0.0341**		-0.0312**
renewables		(0.0128)		(0.0128)
Hydroelectricity			-0.0797*	-0.0434
			(0.0392)	(0.0310)
Water withdrawal per	0.0231	0.0778	0.0864**	0.0666
Capita	(0.0331)	(0.0568)	(0.0400)	(0.0536)
Urbanization	0.256*	0.327*	0.114	0.390***
	(0.141)	(0.164)	(0.164)	(0.141)
Agriculture land	0.140	0.249**	0.404***	0.373**
	(0.112)	(0.121)	(0.135)	(0.136)
Constant	-5.545***	-12.78***	-10.40***	-13.94***
	(1.773)	(2.908)	(2.157)	(2.913)
Observations	440	272	399	259
R^2	0.4395	0.4947	0.3844	0.5140
F	123.26***	116.53***	57.12***	126.29***
Hausman Test	0.0000	0.0825	0.0000	0.0002
Redundant Fixed Effects Tests (LR ratio)				
Cross section F	36.29***	44.52***	34.40***	32.52***
Cross section Chi square	1386.23***	850.02***	1096.99***	730.44***
Time Fixed Effects				
P-value	**0.0478**	**0.001**	**0.013**	**0.0076**
Driscoll and Kray Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

4.4 Two Stage Least Squares (2SLS) Results

Although Fixed effects incorporate country specific characteristics but does not account for time-invariant characteristics of the countries. To incorporate such factors and deal with endogeneity 2SLS is employed (Majeed and Ayub, 2018). Table 5 presents the results obtained from the 2SLS. The results confirm the role of renewable energy in environmental mitigation. Renewable energy consumption or electricity produced from renewables (solar, wind, geothermal, biofuel, biomass, tides) sources and hydroelectricity play an important role in emissions reduction which is indicated by the negative sign of the coefficient. The finding supports social choice theory. The results also confirm the Himalayan environmental degradation theory as anthropogenic activities leads to environmental degradation. Furthermore, water withdrawal increases emissions because of dependence on fossil fuel energy. EKC is also supported. The current study used own lagged values of focused independent variables. For the validity of instruments results of Sargan and Basman tests are reported. The probability of both tests is greater than 5% validating the instruments used.

Table 5: 2SLS Results of Renewable Energy and Water on CO_2

	1	**2**	**3**	**4**
Variables	**lCO_2**	**lCO_2**	**lCO_2**	**lCO_2**
GDP per capita	2.830***	2.903***	2.552***	2.297***
	(0.226)	(0.380)	(0.268)	(0.330)
GDP per capita	-0.124***	-0.120***	-0.110***	-0.0876***
Square	(0.0125)	(0.0203)	(0.0146)	(0.0175)
Renewable energy	-0.272***			
Consumption	(0.0188)			
Electricity from		-0.0908***		-0.0752***
Renewables		(0.0166)		(0.0126)
Hydroelectricity			-0.132***	-0.120***
			(0.0163)	(0.0140)
Water withdrawal	0.0487***	0.0943***	0.0841***	0.0640***
per capita	(0.0180)	(0.0253)	(0.0193)	(0.0212)
Urbanization	0.186*	0.175	0.189	-0.00300
	(0.102)	(0.153)	(0.141)	(0.133)
Agriculture land	0.0501***	0.0172	0.0591***	0.0767***
	(0.0128)	(0.0164)	(0.0178)	(0.0156)
Constant	-13.85***	-14.12***	-12.51***	-11.56***
	(0.999)	(1.668)	(1.109)	(1.430)
Observations	409	248	368	247
R^2	0.881	0.773	0.811	0.817
Adjusted *R^2*	0.879	0.767	0.808	0.812
Wald chi2	3026.14	843.93	1580.40	1106.34
Root MSE	0.5315	0.4786	0.5629	0.4032
Sargan Score	0.4599	4.1718	1.3282	1.5789
p-value	0.4976	0.1242	0.5147	0.2089
Basman Score	0.4515	4.0892	1.3004	1.5312
p-value	0.5016	0.1294	0.5219	0.2159
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

4.5 Sensitivity Analysis

Table 6 reports the results of sensitivity analysis, which is conducted using additional control variables namely trade, inflation, foreign direct investment, and population density (PD). The results are robust and not sensitive to the inclusion of these control variables. Renewable energy affects negatively CO_2 emissions while water withdrawal affects emissions positively and inverted U-shape relationship is supported.

Table 6: Sensitivity Analysis

Variables	**(Trade)**	**(Inflation)**	**(FDI)**	**(PD)**
Renewable Energy	-.2601555***	-.2527894***	-.2327519***	-.2537818***
	(.0202343)	(.0242358)	(.0191885)	(.0173176)
Water Withdrawal	.0453061***	.0335573	.0440046	.046429*
Per Capita	(.0284912)	(.0229801)	(.0299648)	(.022597)
GDP Per Capita	2.779635***	2.749208***	2.977632***	2.73604***
	(.2087937)	(.2362588)	(.1804266)	(.2099671)
GDP Per Capita	-.1214704***	-.1186719***	-.1328604***	-.1190693***
Square	(.0108549)	(.0127632)	(.0097308)	(.0108025)
Switching Variables	-.0312448	.0407156	.0212287	-.0150787
	(.0468281)	(.0351165)	(.0163122)	(.0140409)
R-Squared	0.8763	0.8748	0.8843	0.8741
Electricity From	-.0819807***	-.0902623***	-.0768546***	-.0914325***
Renewables	(.0150224)	(.008608)	(.0136051)	(.0090874)
Water Withdrawal	.1199949***	.0887308***	.1172247***	.0990943***
Per Capita	(.0310666)	(.0174383)	(.027435)	(.0211222)
GDP Per Capita	3.755909***	2.675433***	4.080517***	2.713846***
	(.3558267)	(.3569069)	(.3330468)	(.371791)
GDP Per Capita	-.1640532***	-.1063262***	-.1823985***	-.1088436***
Square	(.0187807)	(.0188197)	(.0169441)	(.0204812)
Switching Variables	.2095059***	.0293381	.0581725***	-.0124018
	(.0612829)	(.0303671)	(.0172392)	(.0205517)
R-Squared	0.8052	0.7885	0.8103	0.7886
Hydroelectricity	-.1438479***	-.1309872***	-.139666***	-.1284834***
	(.0176783)	(.0160065)	(.0164016)	(.0121311)
Water Withdrawal	.0777581**	.0516575	.0618913*	.0707448**
Per Capita	(.0325597)	(.0337194)	(.0327671)	(.0267615)
GDP Per Capita	2.692248***	2.69612***	3.144564***	2.425815***
	(.3521085)	(.3510975)	(.3811734)	(.3592224)
GDP Per Capita	-.1152813***	-.1164577***	-.1406939***	-.1027976***
Square	(.0185802)	(.0192898)	(.0195716)	(.0191342)
Switching Variables	-.0350534	.0755604	.0067586	-.0164046

	(.0550694)	(.0509312)	(.0156436)	(.0173363)
R-Squared	0.8196	0.8101	0.8408	0.7998
Electricity From	-.0765225***	-.0824366***	-.0749055***	-.0809929***
Renewables	(.0127056)	(.0078341)	(.0132631)	(.0086181)
Hydroelectricity	-.1211683***	-.1114091***	-.1220478***	-.108716***
	(.0161234)	(.0142697)	(.0161703)	(.0127386)
Water Withdrawal	. 0928035***	.06016***	.0856832***	.0602192***
Per Capita	(.020622)	(.0116552)	(.0164597)	(.0157163)
GDP Per Capita	3.00835***	2.173814***	3.302811***	2.170002 ***
	(.2692349)	(.4162482)	(.1741063)	(.372193)
GDP Per Capita	-.1222409***	-.0793525***	-.1391631***	-.0794866***
Square	(.0149857)	(.0220178)	(.0094698)	(.0198609)
Switching Variables	.1315021*	.0298352	.0419615***	.0033714
	(.0645724)	(.0283387)	(.0148488)	(.0150321)
R-Squared	0.8447	0.8243	0.8502	0.8247
DK standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

4.6 N-shaped Environmental Kuznets Curve

Table 7 reports the results obtained from the inclusion of N-shaped Kuznets Curve for the sensitivity analysis. The results are consistent and not sensitive to the inclusion of N-shaped Kuznets Curve. Renewable energy causes negative effect on emissions while water withdrawal causes positive effect on emissions. In addition, the results indicate that the N-shaped Kuznets Curve holds.

Table 7: N-shaped Kuznets Curve

Variables	(1)	(2)	(3)
	DK Standard Errors	**Random Effects**	**2-SLS**
GDP per capita	4.268***	4.329***	5.441***
	(1.018)	(1.492)	(1.679)
GDP per capita	-0.303**	-0.410**	-0.436**
Square	(0.114)	(0.178)	(0.201)
GDP per capita	0.00720***	0.0144**	0.0122***
Cubic	(0.00425)	(0.00697)	(0.00788)
Renewable energy	-0.255***	-0.221***	-0.273***
Consumption	(0.0145)	(0.0179)	(0.0188)
Water withdrawal per	0.0452*	0.0736***	0.0457**
Capita	(0.0229)	(0.0225)	(0.0180)
Urbanization	0.226**	0.463***	0.164
	(0.109)	(0.116)	(0.102)
Agriculture land	0.0549***	0.00633	0.0506***
	(0.00805)	(0.0209)	(0.0128)
Constant	-17.88***	-15.45***	-20.94***
	(3.048)	(4.116)	(4.601)
Observations	440	440	409
R-squared	0.874		0.881
Number of groups	166	166	166
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.			

5. Conclusion

Environmental degradation led climate change is a global phenomenon. To combat emissions, collective measures are required at global level. In this regard renewable energy has the potential to offer environmental mitigation without offsetting growth and sustainable development. Therefore, the purpose of this study was to explore the energy-water-environment nexus by analyzing the data of 166 countries over the period 1990-2017. Carbon dioxide (CO2) has been used as a proxy of environmental degradation.

The results obtained from Pooled OLS, Random Effects and Fixed Effects validate Environmental Kuznets Curve. Moreover, the results confirm the negative effect of renewable energy and the positive impact of water withdrawal on environmental degradation. Due to the presence of bidirectional relationship among the environmental degradation and independent variables 2SLS is applied to tackle the problem of endogeneity. The results obtained from 2SLS also support the main findings. A sensitivity analysis also confirms the main findings of this study.

5.1Contribution of the Study

Renewable energy possesses the potential to sustain development without compromising environmental quality however the literature in this regards is quite limited. Only country specific and region specific evidence is available, which cannot be generalized at global level. Furthermore, no attempt has been made previously to capture the effect of water withdrawal on emission at global level. To the best of our knowledge, this study occupies a special position in the literature which combines and integrates renewable energy resources, water withdrawal, and the Environmental Kuznets Curve in a single model to check its effect on environmental degradation. The study used the large panel of 166 countries which covers the aspects of both developed and developing economies because of the nature of the problem. The study also segregated renewable energy into hydroelectricity and renewable electricity (which combines solar, wind, biogas, biofuel, tide and geothermal) and explored its effect on environmental degradation which is missing in the literature. The study incorporated 2SLS to cope up with the problem of endogeneity. Therefore this study attempts to bridge the gaps in Energy-Water-Environment nexus.

5.2 Theoretical/Policy Implications

The raising concerns on global warming caused by environmental degradation lead to the motivation towards conducting this study. The findings are consistent with the literature (Sharif et al., 2019; Koengkan, 2018; Jebli & Youssef, 2017; Rafindadi et al., 2014; Fienen & Arshad, 2016) and support theoretical foundations of “ecological modernization” and “environmental transition” theories, which imply that modernization and technological innovations support the quality of environment. The findings also support clean development mechanism (CDM) and are consistent with the Theory of Himalayan Environmental degradation which considers anthropogenic activities as the basic cause of environmental degradation. The findings also support social choice theory and welfare economics as individuals maximize utility through improved environment and in this regard renewable energy can be helpful as it diversifies energy supply and controls the trend of natural resource depletion.

On the basis of empirical findings the policy implications are that government need to create enabling policy environment that encourages industries and the private sector to manufacture and promote renewable energy consumption and water-efficient technologies. Fossil fuel energy should be substituted with renewable energy as renewable energy is sustainable, ensures energy security, facilitates energy independence, and does not generate externalities. Water rights should be clearly defined and polluter pays principle should be promoted, to improve water resource management and to minimize the effects of contaminated water on society and the environment as a whole.

5.3 Study Limitations

The study has certain limitations: First, this study considers only CO2 emissions as proxy of environmental degradation. Second, a comparative regional analysis is not conducted due to data limitations. Third, this study uses different renewables (solar, wind, geothermal, timed, biofuel and biogas) in the form of a composite indicator because separate series for these renewables were not available.

5.4 Future Study Directions

Future research can extend this analysis for other forms of greenhouse gases and for different dimensions of environmental degradation. This research can be extended for a comparative analysis of different group of countries. A disaggregated analysis for different renewables such as solar, wind, biofuel and biogas can be conducted. Moreover, future research can focus on the role of institutions in environmental mitigation, as institutional quality can lead to enforcement of rules and regulations which lead to improved environment.

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