International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(2), 244-257.

Impact of Urbanization on Environmental Eminence: Moderating Role of Renewable Energy

Kusiyah[1]*, Mansoor Mushtaq[2], Shabbir Ahmed[3], Ansar Abbas[4], Mochammad Fahlevi[5]

[1]Department of Management, Kusuma Negara Business School, Jakarta, Indonesia, [2]FAST School of Management, National University of Computer and Emerging, Sciences, Islamabad, Pakistan, [3]Lecturer, Department of Economics, Government College, Kasur, Pakistan, [4]Hamdard University Islamabad, Pakistan, [5]Department of Management, BINUS Online, Bina Nusantara University, Jakarta 11480, Indonesia. *Email: kusiyah@privietlab.org

Received: 24 February 2023 **Accepted:** 23 November 2023 **DOI:** https://doi.org/10.32479/ijeep.14232

ABSTRACT

In the era of modernization, the movement of the multitude from rural to urban regions all over the globe is rising swiftly. This movement crafts so many socio-economic prospects for the masses. However, in chorus, it has made severe challenges for the eminence of the environment due to a decrease in forestation and the arrangement of more buildings and plants, causing CO_2 emissions. It is unmanageable to edge the endurance of urbanization, and the issue is how we can switch its adversative effects on the environment. This study investigated the moderating role of renewable energy consumption in the urbanization-CO_2 nexus. For this study, twenty-three of the most urbanized economies from around the world were chosen from 1997 to 2021. Three econometrics techniques are applied for empirical investigation: fixed effect model, robust least square and panel quantile regression with twelve model specifications. The dependent variable is carbon dioxide (CO_2) emissions. The explanatory variables are gross fixed capital formation, patent application, inflation, financial development, industrial growth, urbanization and interaction term of renewable energy and urbanization. To check the robustness of empirical findings, we used four different proxies of (CO_2) emissions and three different proxies of urbanization. In our empirical findings, patent application, inflation and industrial growth are positively and significantly associated with all proxies of CO_2 emissions. While financial development is inversely and significantly allied with CO_2 emissions. The impact of all proxies of urbanization is positive and significant on CO_2 production. But the moderating effect of renewable energy on environmental depredation is inverse and significant. It suggests using clean and renewable energy and developing the financial sector to improve the eminence of the environment. Our research aligns with the sustainable development goals and the corporate social responsibility stream, making some valuable contributions to the body of previously established research.

Keywords: CO_2 Emissions, Urbanization, Renewable Energy, Fixed Effect Model, Robust Least Square, Panel Quantile Regression
JEL Classifications: Q54, Q43, R11, O44, C23

1. INTRODUCTION

In recent years, corporate social responsibility (CSR) has emerged as an important topic, with many Fortune 500 businesses setting lofty targets for increasing their use of renewable energy. Many of these businesses see using sustainable energy sources, such as solar and wind, as fundamental to achieving their sustainability objectives. The success of CSR initiatives can be supported by mitigating energy costs through increased usage of renewables, which has a lot of implications (Strielkowski et al. 2021). In addition to CSR, the three fundamental theories that link sustainability and industry are the stakeholder theory, corporate sustainability, and green economics (Chang et al. 2017). Environmental CSR works to lessen the negative impact that a company's operations have on the surrounding environment. It is primarily concerned with energy use, water consumption, sanitation, recycling, emission levels, environmentally friendly workplace rules, and corporate travel regulations (Sheehy and Farneti, 2021). The United Nations'

17 Sustainable Development Goals are crucial roadmaps for the progress of underdeveloped nations. Yet, reaching this kind of objective is only feasible when they are in concord with one another (Guzel et al., 2021). In order to be considered stable, urban sprawl must not only include the conversion of natural resources land into urban areas without causing any alterations to the natural environment, but it must also involve significant shifts in the structure, economic growth, population, and urban ecosystems (Pickett et al., 2013)

People are relocating to cities in more significant numbers in developing and developed countries. It has become a modern trend in today's globalized sphere. This rapid urbanization in recent decades across the world, particularly in developed economies, has raised serious concerns about environmental damage. Urbanization, measured by the urban population as a percentage of the total population, is increasing in almost every country of the world due to increased rural-urban migration. People move to cities for better employment, education, health care and a higher quality of life (Kasman and Duman, 2015, Yazdi and Darian, 2019). The progress of urbanization is inextricably linked to the process of industrialization. Urbanization shifts economies away from simple agriculture and more towards more advanced productive sectors such as industry and services. Urbanization and industrialization are strongly connected (Raheem and Ogebe, 2017; Malik et al., 2017). A similar argument is that economic growth motivates urbanization and industrialization (Pugh, 1995; Hope, 1998).

However, a counter-narrative against urbanization is that although bigger cities are venues of economic growth, they become a source of environmental degradation. The reason for this is decreased forestation and CO_2 emissions (Karsenty et al., 2003) and more buildings and factories (Feng et al., 2019). Second, as the pace of urbanization rises, so does the Population and economic activity, increasing carbon emissions. (Pata, 2018; Chowdhury et al., 2019). Third, when more people move to big cities, they increase the consumption of electricity (Du et al., 2015) and more energy (Xuemei et al., 2012; Chen et al., 2014; Rahman and Vu, 2020) which becomes a source of increase in emissions of carbon dioxide (Dhami et al., 2013; Rayhan and Islam, 2015; Raheem and Ogebe, 2017; Sohag et al., 2017; Rahman and Vu, 2020).

Various empirical studies show that urbanization is a crucial aspect in influencing environmental quality adversely (Grimm et al., 2008; Poumanyvong and Kaneko, 2010; Martinez-Zarzoso and Maruotti, 2011; Hossain, 2012; Al-mulali et al., 2013; Sadorsky, 2014; Li and Lin, 2015; Dogan and Turkekul, 2016; Wang et al., 2018; Shahbaz et al., 2016; Ali et al., 2019 among others). One of the significant contributions to CO_2 emissions is fossil fuel energy. CO_2 emissions have grown due to the consumption of oil and fossil fuels throughout the process of obtaining high growth rates through industrialization, particularly in emerging economies. Natural resource depletion and growing demand for traditional energy sources have prompted policymakers to look for alternate energy sources (Toklu, 2013). Energy consumption is directly associated with carbon dioxide emissions (Reddy and Assenza, 2009). Nonrenewable energy sources, such as coal and petroleum, lead to the deterioration of the environment (Ahmadov and van der Borg, 2019). Traditional energy sources used in manufacturing harm the environment. As a result, there is a trade-off between economic expansion and the environment, suggesting that environmental damage is a natural consequence of higher economic growth. However, the utilization of clean energy and environmentally friendly technology in both domestic and international arenas is receiving more attention from environmentalists, international organizations, and governments (Ozturk and Yuksel, 2016). Consequently, renewable (biomass, hydro, wind, solar and nuclear) energy should be viewed as a viable option for boosting the energy supply while reducing CO_2 emissions (Menyah and Wolde-Rufael, 2010; Apergis et al., 2010; Sinha et al., 2017; Riti and Shu, 2016; Allard et al., 2018; Pata, 2018). There are empirical studies that confirm that renewable energy is a source of improvement in an environment (Wang and Dong, 2019; Destek and Sinha, 2020; Iorember et al., 2020; Kayani et al., 2024; Nathaniel and Khan, 2020; Sharif et al., 2020; Topcu, 2021).

The current study contributes to the previously standing literature in the subsequent means: Unlike previous studies, this study checks the moderating role of renewable energy usage in the urbanization-CO_2 nexus. In this way, the findings of this study will be able to provide an empirical assessment of how nations ought to react to growing urbanization to address the problem of environmental degradation.

The leftover study is intended as follows: Section 2 appraises the literature. Part 3 presents model specification, variable description and data sources. The methods, as well as the empirical findings, are discussed in Part 4. The fifth section concludes the study, which also makes recommendations for future research and policy guidelines.

2. LITERATURE REVIEW

2.1. Nexus between Urbanization and Environmental Eminence

The first research of literature argues that urbanization leads increase CO_2 emissions. The channel through which this might occur is because urbanization is a critical component that increases energy consumption and, as a result, CO_2 emanations (Parikh and Shukla, 1995; Cole and Neumayer, 2004; York, 2007; Elheddad et al., 2020; Abbasi et al., 2020; Rehman et al., 2021). Similarly, Al-mulali et al. (2013) argue that urbanization enhances the consumption of energy of dominantly fossil fuels, increasing pollution. This argument has been augmented by empirical studies (York et al., 2003; Lin and Liu, 2010; Kashem and Rahman, 2019). Zhu and Peng (2012) describe how urbanization influences CO_2 emissions through three distinct routes. First, as a city's population grows, so does household consumption and energy demand, resulting in increased CO_2 emissions. Second, urbanization typically increases demand for housing, which in turn increases demand for house materials, which are known to be essential producers of CO_2. Finally, as the demand for homes rises, trees and grassland activities will be removed, releasing the carbon in the trees. Parikh and Shukla (1995) determines how urbanization influences CO_2 releases. They use cross-section data from 83 industrialized and emerging countries from 1986. According to the study, the elasticity of CO_2 production concerning urbanization is 0.036. York et al. (2003) use data from 137 countries to show that as cities increase, so do CO_2 emissions. According to the study, the elasticity of CO_2 emanations about urbanization is 0.624.

Cole and Neumayer (2004) show a positive effect of urbanization on CO_2 production using data from 86 countries from 1975 to 1998. Alam et al. (2007) explore urbanization's influence on Pakistan's environmental quality. They discover that urbanization has an enormously beneficial impact on CO_2 production. On the other hand, Liddle and Lung (2010) find a positive but negligible influence of urbanization on CO_2 emissions when cumulative carbon dioxide releases are used as the dependent variable and a positive and substantial relationship when carbon dioxide from transportation is used as the dependent variable. Poumanyvong and Kaneko (2010) use panel data from 99 countries separated into three subgroups to evaluate the influence of urbanization on CO_2 releases. Their findings show that urbanization substantially positively influences CO_2 production across all income categories, with a more substantial effect in the middle-income groups compared to other income groups. Similarly, research by Xu and Zhou (2011) found that urbanization raised carbon emissions in China, and urbanization will continue to do so.

Shahbaz et al. (2014) scrutinize the connection between urbanization and the environment in UAE from 1975 to 2011, concluding that urbanization increases carbon emissions. According to Zhu and Peng (2012), urbanization is a significant reason for CO_2 release in China. The elasticity of CO_2 about urbanization in China is 0.33, according to the researchers. Similarly, Wang et al. (2013) conducted a study from 1980 to 2009 to determine the influence of urbanization on environmental excellence in ASEAN nations. They discover that a 1% upsurge in urbanization affects a 0.20% upsurge in the production of CO_2. Al-mulali et al. (2013) examine the relationship between urbanization and CO_2 emissions in MENA countries. The data indicate that urbanization has a sizeable constructive impact on CO_2 discharges. Brantley and Liddle (2014) discover a link between urbanization and CO_2 discharges in OECD nations. Their data suggest that urbanization grows CO_2 production.

Sadorsky (2014) examines the influence of urbanization on CO_2 production for a panel of 16 rising economies. According to the findings, there is a considerable positive overtone between urbanization and CO_2 emanations. Liddle (2014) used the GMM approach to investigate the link between urbanization and CO_2 emissions. The findings suggest that urbanization upsurges CO_2 production. Çetin and Ecevit (2015) examine 19 Sub-Saharan African republics from 1985 to 2010, discovering that urbanization is a crucial cause of environmental degradation. A study by Adusah-Poku (2016) finds a positive association between urbanization and CO_2 emission in 45 Sub-Saharan African countries. Using data from four south Asian countries, Azam and Khan (2016) study the impact of urbanization on the deterioration of the environment. They discover that this impact is insignificantly positive for Pakistan and significantly upbeat for Sri Lanka. However, it is significantly negative for India and Bangladesh.

Wang et al. (2016) explore the outcome of urban population areas on the production of CO_2 for BRICS economies. They find that urbanization is a source of increasing carbon emissions. Similarly, Dogan and Turkekul (2016) find that urbanization deteriorates the quality of the environment in the USA. Using data for Latin America and Caribbean countries from 1990 to 2015, Hanif (2017) finds a positive and significant role of urbanization in carbon emissions. From 1996 to 2010, Yi et al. (2017) examined pollution indicators in China. The data suggest that urbanization harms the environment. The authors argue that good spatial resettlement planning is critical for reducing the environmental cost of urbanization. Hanif (2018) uses panel data to scrutinize the impression of urbanization on discharges of carbon in 12 developing nations in East Asia and the Pacific region. Urbanization is one of the primary causes of carbon discharges, according to GMM estimates. In another study by Ali et al. (2019), the contribution of role in emissions of CO_2 was analyzed for Pakistan from 1972 to 2014. The results of ARDL and VECM methods show that urbanization is a source of increasing greenhouse emissions in the short and long term. Along the same lines, Adams et al. (2020) checked the association between urbanization and the degradation of the environment in 19 Sub-Saharan African nations from 1980 to 2011. The results reveal that urbanization is a reason for carbon emissions in the long run. The recent studies by Ahmad et al. (2019), Kirikkaleli and Kalmaz (2020), Wang et al. (2020), Nathaniel et al. (2021), Nguyen et al. (2021) and Wang and Wang (2021) show the same results that urbanization is one of the significant contributors in environmental deterioration.

The second strand of literature argues that urbanization may decrease CO_2 discharges. The channel via which this might occur is that as urbanization increases, effective use of public transportation and other utilities can decrease CO_2 emissions (Liddle, 2004; Poumanyvong and Kaneko, 2010). This argument has been supported by empirical studies (Hossain, 2011; Zhao et al., 2013; Gasimli et al., 2019), among others. Sharma (2011) procedures a dynamic panel data model to examine the drivers of CO_2 production for a worldwide panel of 69 nations. According to the study, urbanization and CO_2 emissions have a statistically noteworthy undesirable connection. Chen and Huang (2013) examine data from N-11 nations from 1981 to 2009 and show a statistically significant negative relationship between urbanization and carbon emissions. According to Ali et al. (2017), urbanization is a source of improved environmental quality. According to Niu (2019), who uses provincial panel data for China from 2002 to 2016, urbanization positively impacts the quality of the environment in Chinese provinces.

The third strand of literature finds that urbanization may have a nonlinear association with CO_2 emissions. Environmental indicators may have an inverted U-shaped or U-shaped connection with urbanization, according to Ehrhardt-Martinez et al. (2002). Martinez-Zarzoso and Maruotti (2011) examine urbanization's impact on CO_2 emissions in emerging nations from 1975 to 2003. Their data show an inverted U-relationship between urbanization and CO_2 production. On the influence of urbanization on carbon production in the Pearl River Delta area, Xu et al. (2018) found a similar result. Martnez-Zarzoso and Maruotti (2011) also establish an inverted U-shaped relationship between CO_2 emissions and urbanization in 88 developing countries. Rafiq et al. (2016) found an inverted U-shaped link between urbanization and carbon emissions. Bekhet and Othman (2017) discovered that early urbanization had a favorable influence on environmental deterioration in Malaysia. However, with more urbanization, there is an improvement in environmental degradation.

Similarly, Zhang et al. (2017) find an upturned U-shaped association between urbanization and carbon dioxide production in developed economies. Shi et al. (2017) scrutinize the outcome of urbanization on carbon production in various urban locations. They observed that increasing urbanization in the leading and next-tier areas would increase carbon production. In contrast, increasing urbanization in the third-tier regions would decrease carbon emissions.

In contrast to these findings, Shahbaz et al. (2016) discovered a U-shaped link between Malaysian urbanization and CO_2 production. Urbanization decreases CO_2 emissions at first but then raises them after a certain point. Therefore, several studies on the liaison between urbanization and environmental deterioration have been conducted utilizing various samples and periods. The overall results of these studies are not the same and need more empirical estimation.

2.2. Nexus between Renewable Energy Consumption and Environmental Eminence

Because of concerns about sustainable growth, the link between economic expansion, energy (fossil energy) usage, and environmental deterioration has gotten much attention in the literature. However, the environmental effect of renewable energy and urbanization is under- researched, especially in highly urbanized and industrialized countries. The literature on renewable energy's influence on environmental quality is less clear. The first line of evidence shows that renewable energy is favorable to environmental quality improvement. Human well-being is linked to the adoption of renewable energy. It will undoubtedly result in substantial economic and social growth changes, which is critical in tackling climate change and improving future living conditions. Accordingly, the advancement of renewable energy has garnered much scientific interest.

Scholars from around the globe have conducted a significant study on the relationships between renewable energy, economic, social, and environmental aspects from many angles (He et al., 2021). Sadorsky (2009) presented one of the first studies on the connection between environmental degradation and renewable energy, examining the causative rapport for 18 developing republics between 1994 and 2003. The result confirmed the neutrality hypothesis in the short term but the conservation theory in the long term. Similarly, the link between renewable energy and CO_2 production for the BRICS nations has been explored throughout 1971-2010 by Sebri and Ben-Salha (2014) and others by totaling trade openness to the independent variable of the production function. The consequences of the bound ARDL test support the preservation premise for South Africa and India.

Silva et al. (2012) analyze the influence of renewable energy on electricity generation in four nations of varying economic development and find that increasing the portion of renewable energy in electricity generation reduces CO_2 discharges. Another study by Apergis and Payne (2014) examines the drivers of renewable energy in the 25 OECD countries. Long-term relationships between renewable energy consumption, CO_2 production, and other factors are revealed via co-integration and error correction model testing. Similarly, Zeb et al. (2014) examine SAARC nations to investigate whether there are any relationships between renewable energy intake, poverty, GDP, and resource depletion. The findings indicate a strong link. Ahmad et al. (2016) investigate the relationship among CO_2, energy depletion, and development for the Indian economy from 1971 to 2014, highlighting that the variables co-integrate and that the EKC is verified at disaggregated and aggregated levels. According to Baek (2016), employing renewable energy negatively influences CO_2 production in the USA.

Asumadu-Sarkodie and Owusu (2017) study the link between energy consumption and environmental quality in Senegal. They contend that employing green energy may enhance environmental quality. Paramati et al. (2017) found that renewable energy consumption has a contrary connection with CO_2 production in a study on the relevance of renewable energy usage for environmental preservation in the Next 11 rising economies. Dong and Hochman (2017) propose natural gas and renewable energy consumption for ecological sustainability. Their work supports the EKC for BRICS economies. Furthermore, the causality study illustrates the rapport between renewable energy, natural gas and economic progress.

Cherni and Jouini (2017) propose that green energy may be used as an alternative to traditional energy sources to reduce greenhouse gas emissions after reviewing Tunisian yearly data. Liu et al. (2017) investigate the connection between nonrenewable and renewable energy, agriculture, and pollution in the BRICS economies. The investigation findings confirmed that green energy had a detrimental impact on pollutant emissions. Similarly, Berkun et al. (2019) use data from 16 E.U. countries from 1996 to 2014 to demonstrate that renewable energy depletion reduces CO_2. Balsalobre-Lorente et al. (2018) examine the link between CO_2 production and economic growth in five major European countries and discover that the collaboration between economic growth, trade openness and renewable electricity depletion rallies environmental eminence by dipping CO_2 production.

Based on data from 28 E.U. states from 1995 to 2015, Akadiri et al. (2019) suggest that developing renewable energy is a steadfast approach to minimizing environmental pollution. Dong et al. (2019) examine essential carbon emission effect elements utilizing a large sample of 128 countries, the most recent methodology, and accounting for cross-section dependency and slope variability; overall results demonstrate a destructive link between renewable energy and emissions of carbon. Usman et al. (2020) show that renewable energy reduces CO_2 production while improving environmental quality. Destek and Aslan (2020) look at how different forms of renewable energy impact C.E.s in G7 nations. Hydropower, biomass, and wind energy are shown to be beneficial in decreasing carbon emissions, but solar energy has a negligible impact.

Usman et al. (2020) used the nonlinear ARDL technique to look at the link between CO_2 emissions and renewable energy consumption for the Pakistani economy from 1975 to 2018. The results confirm the asymmetries in the long and short-term relationship between variables. According to Zafar et al. (2020), green technology should be increased in 27 OECD nations to create reduced carbon emissions. Kahia et al. (2021) expands earlier research on environmental economics literature by evaluating a probable link between economic growth, green energy, and environmental quality in the instance of Saudi Arabia over the period 1990-2016 using the simultaneous equation modeling technique. The study's primary findings include two-way interactions between economic growth and CO_2 emissions, as well as CO_2 emissions and renewable energy utilization. Using a Spatio-temporal approach, Grodzicki et al. (2022) examined the effects of urbanization and renewable energy on CO_2 output in Europe from 1995 to 2018. The investigation showed that while an increase in urbanization levels degrades air quality, a rise in the fraction of renewable energy consumption reduces CO_2 production. Djellouli et al. (2022) studied the effect of both renewable and nonrenewable energy and the environmental sustainability of African economies. They found that nonrenewable energy had adverse while renewable energy had positive effects on sustainability. Murshed et al. (2022) investigated the impact of renewable energy use and economic progress on ecological development in South Asian economies. Renewable energy and environmental improvement were shown to have a favorable and substantial relationship. Utilizing the moment of quantile regression, Yang et al. (2022) discovered that renewable energy reduces consumption-based CO_2 production in both the local area and surrounding nations. Gieratowska (2022) used fixed effects regression and a two-step system generalized technique of moments to analyze the overtone among renewable energy, urbanization and CO_2 productions in 163 countries between 2000 and 2016. According to empirical data, consumption of renewable energy decreases CO_2 releases but urbanization raises them in an upturned U-pattern.

The second strand of literature contends that there is no difference between nonrenewable and renewable energy in terms of carbon emissions and pollution. Farhani and Shahbaz (2014) investigate the effect of renewable and nonrenewable energy depletion on CO_2 production in the MENA region and discover that both energy sources contribute to CO_2 production. Similar conclusions have been made by Bilgili et al. (2016) for 17 OECD nations and Mert and Boluk (2016) for 16 European nations. Aguir (2021) uses the GMM estimator to examine the effects of population growth, economic development, urbanization, fossil fuel use, energy productivity, and renewable energy on CO_2 production for 18 MENA nations over the period 2000–2018. Results validate the Kuznets curve for the environment and demonstrate how energy efficiency contributes to environmental improvement. However, environmental quality is not considerably impacted by the amount of renewable energy used in the energy mix.

Additionally, solar energy helps cut down on pollutants. However, these countries' chosen wind and hydropower energy levels do not enable them to enhance their environmental conditions. Similarly, Adedoyin et al. (2021) examined the link between energy growth and CO_2 production in 32 Sub-Saharan African nations and found that using renewable energy increases CO_2 production.

3. MODEL SPECIFICATION AND DATA

The general description of the model can be written as follows:

$$CO_2 = (\text{LNGFC, LNPA, INF, F.D., ING, URBN}) \quad \text{(A)}$$

After introducing the moderating role of renewable energy

$$CO_2 = (\text{LNGFC, LNPA, INF, F.D., ING, URBN, RE*URBN}) \quad \text{(B)}$$

In the econometric model, this can be stated as follows:

$$CO2_1 = \beta_{01} + \beta_{11} LNGFC + \beta_{21} LNPA + \beta_{31} INF + \beta_{41} FD + \beta_{51} ING + \beta_{61} URBN + \beta_{71} R*URBN + \mu \quad (1)$$

The specifications (1-4) are used to check the robustness of model (B) by changing the proxy of CO_2 emissions as follows:

$$CO2_2 = \beta_{02} + \beta_{12} lnGFC + \beta_{22} lnPA + \beta_{32} INF + \beta_{42} FD + \beta_{52} ING + \beta_{62} URBN + \beta_{72} R*URBN + \mu \quad (2)$$

$$LNCO2_3 = \beta_{03} + \beta_{13} lnGFC + \beta_{23} lnPA + \beta_{33} INF + \beta_{43} FD + \beta_{53} ING + \beta_{63} URBN + \beta_{73} R*URBN + \mu \quad (3)$$

$$LNCO2_4 = \beta_{04} + \beta_{14} lnGFC + \beta_{24} lnPA + \beta_{34} INF + \beta_{44} FD + \beta_{54} ING + \beta_{64} URBN + \beta_{74} R*URBN + \mu \quad (4)$$

using the dependent variable of specification (1-4), the specification (5-12) is used to check the robustness of models with interaction terms by changing the proxies of urbanization. Interaction terms of renewable energy and urbanization are as follows:

$$CO2_5 = \beta_{05} + \beta_{15} LNGFC + \beta_{25} LNPA + \beta_{35} INF + \beta_{45} FD + \beta_{55} ING + \beta_{65} URBN + \beta_{75} R*URBN + \mu \quad (5)$$

$$CO2_6 = \beta_{02} + \beta_{12} lnGFC + \beta_{22} lnPA + \beta_{32} INF + \beta_{42} FD + \beta_{52} ING + \beta_{62} URBN + \beta_{72} R*URBN + \mu \quad (6)$$

$$LNCO2_7 = \beta_{07} + \beta_{17} lnGFC + \beta_{27} lnPA + \beta_{37} INF + \beta_{47} FD + \beta_{57} ING + \beta_{67} URBN + \beta_{77} R*URBN + \mu \quad (7)$$

$$LNCO2_8 = \beta_{08} + \beta_{18} lnGFC + \beta_{28} lnPA + \beta_{38} INF + \beta_{48} FD + \beta_{58} ING + \beta_{68} URBN + \beta_{78} R*URBN + \mu \quad (8)$$

$$CO2_9 = \beta_{09} + \beta_{19} LNGFC + \beta_{29} LNPA + \beta_{39} INF + \beta_{49} FD + \beta_{59} ING + \beta_{69} URBN + \beta_{79} R*URBN + \mu \quad (9)$$

$$CO2_{10} = \beta_{010} + \beta_{110} lnGFC + \beta_{210} lnPA + \beta_{310} INF + \beta_{410} FD + \beta_{510} ING + \beta_{610} URBN + \beta_{710} R * URBN + \mu \quad (10)$$

$$LNCO2_{11} = \beta_{011} + \beta_{111} lnGFC + \beta_{211} lnPA + \beta_{311} INF + \beta_{411} FD + \beta_{511} ING + \beta_{611} URBN + \beta_{711} R * URBN + \mu \quad (11)$$

$$LNCO2_{12} = \beta_{012} + \beta_{112} lnGFC + \beta_{212} lnPA + \beta_{312} INF + \beta_{412} FD + \beta_{512} ING + \beta_{612} URBN + \beta_{712} R * URBN + \mu \quad (12)$$

Panel data from 23 developed and highly urbanized countries have been used for empirical exploration[1]. These countries have a high percentage of urban population as a percentage of the total Population. For instance, among these countries, Australia, Belgium, Brazil, Canada, Chile, Colombia, Denmark, France, Greece, Hong Kong, Japan, Mexico, Netherlands, New Zealand, Spain, Sweden, UK and USA consist of 86%, 98%, 87%, 81%, 87%, 81%, 88%, 81.2%, 80%, 100%, 91.8%, 81%, 92%, 86%, 81%, 88.2%, 84% and 82.8% urban population as a share of total Population. The range of our data set is 1997 to 2021, with yearly regularities. The dependent variable is carbon dioxide (CO_2) emissions measured by four proxies, i.e., CO_2 emissions (kg per 2015 US$ of GDP) ($CO2_1$), CO_2 emissions (kg per PPP $ of GDP) ($CO2_2$), natural log of CO_2 emissions (kt) ($LNCO2_3$) and the natural log of CO_2 emissions from solid fuel consumption (kt) ($LNCO2_4$). Explanatory variables are gross fixed capital formation measured by the natural log of gross fixed capital formation (current US$), patent application (a proxy of technological improvement) measured by the natural log of patent applications, and residents. The third independent variable of the model is inflation, measured by inflation of consumer prices (annual %), and financial development (F.D.) is measured by Domestic credit to the private sector (% of GDP). Another independent variable is industrial growth measured by Industry (including construction), and values added (annual % growth). Three alternatives measure urbanization (URBN), i.e., Urban population growth (annual %) is used by 1-4 specification, Population in the largest city (% of urban population) is used by 5-6 specification, and the natural log of Population in largest city is used by 9-12 specification. Renewable energy is measured by renewable energy consumption (% of total final energy consumption). It has been used as a mediator to show the indirect linkage between CO_2 omissions and urbanization. Data has been taken from world development indicators (WDI) and World Economic Outlook (WEO).

4. METHODOLOGY AND RESULTS

In the first stage, we obtained the empirical finding using a fixed effect model. When using Fixed Effect, we assume that something within the cross-section can have an impact or bias in explained or explanatory variables, which must be overcome. This is the reasoning based on the assumption of a correlation between the individual's error term and the explained variables. We may compute the regressors' net effect on the regressand. Hausman (1978) developed the test to distinguish between the Fixed Effect Model and the Random Effects Model. The null hypothesis states that the random effects model is acceptable for estimating the empirical model. In contrast, the alternative hypothesis states that the fixed effect model is adequate.

We also employed Robust Least Square to perceive the empirical verdicts' robustness. The most effective approach is ordinary least square estimates (OLS) subject to the contentment of underlying assumptions. If some of these assumptions are not satisfied, it will give deceptive outcomes. Consequently, OLS is said to be not robust. Moreover, Ordinary least square (OLS) estimates in multiple regressions are severely affected by outliers, non-normality, multicollinearity, and missing data. These outliers have a substantial adverse effect both in the direction of explained and predictor variables, and they may remain unnoticed. Robust regression in the form of Huber M Estimates, MM Estimates and S Estimates overcomes the influence of extreme observations (Staudte and Sheather, 1990; Rousseeuw and Yohai, 1984 and Ho and Naugher, 2000). M Estimates define a general function of residuals $H(\varepsilon_i)$, and then minimizing $S=\Sigma H(\varepsilon_i)$. For OLS $H(\varepsilon_i)=\varepsilon_i^2$. The properties we want for the function H; always non- negative $= H(\varepsilon_i) \geq 0, H(0)=0$, symmetric, $H(\varepsilon_i)=H(\varepsilon_i)$, monotonic: if $|\varepsilon_j| > |\varepsilon_j|$ then $H(\varepsilon_i) > H(\varepsilon_i)$. For least – squares regressions: $S=\Sigma \varepsilon_i^2$.

Diff. w.r.t. parameter and keep equal to zero

$$\frac{\partial S}{\partial \beta_k} = 0 \rightarrow \sum_{i=1}^{i=0} \varepsilon_i x_{it} = 0 \quad (13)$$

For M- Estimators,

$$\frac{\partial S}{\partial \beta_k} = 0 \rightarrow \sum_{i=1}^{i=0} \frac{\partial H}{\partial \varepsilon_i} x_{ki} = 0 \quad (14)$$

Define weight as

$$w_i = \frac{1}{\varepsilon_i} \frac{\partial H}{\partial \varepsilon_i} \quad (15)$$

Giving

$$\sum_{i=1}^{n} \frac{\partial H}{\partial \varepsilon_i} x_{ki} = 0 = \sum_{i=1}^{n} \frac{\partial H}{\partial \varepsilon_i} w_i \varepsilon_i x_{ki} \quad (16)$$

But this is just a weighted linear regression! Guess the weight and fit, then calculate the residuals. Use those residuals to calculate the new weights. Repeat until convergence called interactively reweighted Least Squares.

The third econometric technique used for empirical investigation is Panel quantile Regression calculates the conditional median (or other quantiles) of the response variable as opposed to the method of least squares, which calculates the conditional mean of the response parameter across values of the predictors. When the prerequisites for linear regression are not met, the linear regression extension known as quantile regression is applied (Graham et al.,

1 Australia, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Russia, Spain, Sweden, UK, USA

2015; Gu et al., 2019). The quantile regression estimates are more resistant to outliers in the response measurements, which is one benefit of quantile regression over standard least squares regression (Canay, 2011).

4.1. Empirical Findings

Empirical findings can be accessible from Tables 1-4.

The Hausman Test results subsequent in Table 1 have declined the supremacy of the Random effect model specification (1-12). P-value designates the appropriateness of the fixed-effect model for further analysis.

Table 1: Hausman test results

Null Hypothesis: Random effect model is applicable			
Specifications	**Chi-square statistic**	**Chi-Sq. D.F**	**Probability**
1	65.107343	7	0.0000
2	29.602157	7	0.0001
3	20.668835	7	0.01537
4	25.875101	7	0.0442
5	49.343380	7	0.0000
6	59.706818	7	0.0000
7	24.737120	7	0.0008
8	21.623059	7	0.0029
9	51.234907	7	0.0000
10	33.238131	7	0.0000
11	17.589660	7	0.0140
12	16.797382	7	0.0188

Table 2 presents the results of regressions obtained through the fixed effect model. The dependent variable is carbon dioxide (CO2) emissions. It is measured by four proxies, i.e., CO2 emissions (kg per 2015 US$ of GDP) ($CO2_1$), CO_2 emissions (kg per PPP $ of GDP) ($CO2_2$), natural log of CO2 emissions (kt) ($LNCO2_3$) and the natural log of CO2 emissions from solid fuel consumption (kt) ($LNCO2_4$). Explanatory variables are gross fixed capital formation, patent application, inflation, financial development (F.D.), industrial growth, urbanization and interaction term of renewable energy and urbanization. Three alternatives measure urbanization (URBN), i.e., Urban population growth (annual %) is used by 1-4 specification, Population in the largest city (% of urban population) is used by 5-6 specification, and the natural log of Population in largest city is used by 9-12 specification. In our empirical findings, LNGFC has an inconclusive impact on CO2 omission from 1-12 regressions. Investment or capital stock may increase or decreases the level of CO_2 production depending upon the consumption of the type of energy and environment policy. In our findings, patent application or innovations, inflation and industrial growth are positively and significantly associated with all proxies of CO_2 emissions. While financial development is inversely and significantly associated with CO_2 emissions. In almost all specifications, the impact of all proxies

Table 2: Fixed effect results

Independent Variables	$CO2_1$	$CO2_2$	$LNCO2_3$	$LNCO2_4$
	Equation 1	**Equation 2**	**Equation 3**	**Equation 4**
LNGFC	−0.140211 (−6.050875)*	−0.135548 (−9.137054)*	0.400843 (8.224497)*	0.253396 (2.912735)*
LNPA	0.138376 (10.37075)*	0.100676 (11.80672)*	0.393104 (14.03245)*	0.451529 (9.715074)*
INF	0.032435 (7.490403)*	0.015426 (5.425358)*	0.071218 (7.624326)*	0.067275 (4.473137)*
FD	−0.001795 (−5.166472)*	−0.000601 (−2.692011)*	−0.006582 (−8.974747)*	0.000349 (0.315775)
ING	0.011903 (3.939062)*	0.010256 (5.164796)*	0.009145 (1.401811)	0.048183 (4.515861)*
URBN (P-1)	0.155122 (6.742868)*	0.141024 (9.448864)*	0.509539 (10.39175)*	0.572905 (6.661578)*
RE*URBN (P-1)	−0.002490 (−3.436667)*	−0.003197 (−6.805624)*	−0.010310 (−6.679447)*	−0.010759 (−3.875461)*
Constant	2.785811 (5.436042)*	2.883819 (8.770874)*	−1.131172 (−1.047194)	0.054610 (0.028419)
R^2	0.539008	0.509049	0.880655	0.771290
Adjusted R^2	0.497100	0.466890	0.870406	0.748711
	Equation 5	**Equation 6**	**Equation 7**	**Equation 8**
LNGFC	−0.081854 (−3.557193)*	−0.100086 (−6.967719)*	0.568524 (11.47211)*	0.403966 (4.955149)*
LNPA	0.095909 (7.388693)*	0.061714 (7.602753)*	0.256993 (9.176603)*	0.393833 (8.721460)*
INF	0.036167 (7.921452)*	0.018483 (6.319058)*	0.084393 (8.362957)*	0.062455 (4.160736)*
FD	−0.001105 (−2.973125)*	0.000187 (0.796359)	−0.004152 (−5.137127)*	−0.001261 (−0.998264)
ING	0.019817 (6.550561)*	0.017070 (8.790979)*	0.034963 (5.218934)*	0.069605 (6.989270)*
URBN (P-2)	0.000423 (0.261155)	0.001454 (1.423778)	0.006943 (1.970943)**	0.010656 (3.342946)*
RE*URBN (P-2)	−0.000135 (−2.488653)*	−0.000253 (−7.380185)*	−0.000701 (−5.930062)*	−0.000934 (−5.700118)*
Constant	1.693630 (3.150849)*	2.338810 (6.958018)*	−4.214773 (−3.634474)*	−2.757651 (−1.455411)
R^2	0.481156	0.470999	0.858186	0.773473
Adjusted R^2	0.433989	0.425572	0.846008	0.751109
	Equation 9	**Equation 10**	**Equation 11**	**Equation 12**
LNGFC	−0.104235 (−4.512182)*	−0.089980 (−6.044901)*	0.443050 (9.704512)*	0.263976 (3.211616)*
LNPA	0.094275 (7.490133)*	0.064415 (7.906238)*	0.242193 (9.692178)*	0.362544 (8.702494)*
INF	0.031238 (6.685432)*	0.016751 (5.406461)*	0.054931 (5.780353)*	0.035839 (2.319402)**
FD	−0.001090 (−3.039592)*	−0.0601024 (−0.382289)	−0.003492 (−4.880017)*	0.000374 (0.349389)
ING	0.020822 (7.119654)*	0.017039 (8.755698)*	0.037581 (6.296283)*	0.073552 (7.569771)*
URBN (P-3)	0.056272 (3.371940)*	0.020717 (1.908065)**	0.322509 (9.684496)*	0.349535 (6.341256)*
RE*URBN (P-3)	−0.000292 (−4.526036)*	−0.000296 (−7.030377)*	−0.001066 (−8.267936)*	−0.001412 (−6.365570)*
Constant	1.463783 (3.084828)*	1.782677 (5.770514)*	−5.648763 (−5.961739)*	−4.103464 (−2.450104)*
R^2	0.508314	0.461414	0.885892	0.785729
Adjusted R^2	0.463616	0.415164	0.876094	0.764575

P-1, P-2, and P-3 specify proxy1, proxy 2 and proxy 3, respectively. T values are in parentheses.*, ** and ***, indicating the level of significance at 1%, 5% and 10%, respectively of urbanization is positive and significant on CO_2 production. But the moderating impact of renewable energy on environmental depredation is inverse and significant.

Table 3 presents the results of regressions (1-12) obtained through Robust Least Square. In our empirical findings, Like the fixed effect model, LNGFC has an inconclusive impact on CO_2 omission in this model. While applying Robust Square, patent applications or innovations positively impact ten specifications but are inverse and significant in 2 specifications. Inflation is positively and significantly associated with all proxies of CO_2 emissions. While financial development is inversely and significantly associated with CO_2 emissions. Industrial growth is positively and significantly associated with all proxies of CO_2 emissions in almost all specifications except one or two, where its impact is insignificant. In almost all specifications, the impact of all proxies of urbanization is positive and significant on CO_2 production. But the moderating impact of renewable energy on environmental depredation is inverse and significant.

Table 4 states the results of regressions (1-12) acquired over Panel Quantile Regression. Not entirely; the results of Panel

Table 3: Robust least squares

Independent Variables	$CO2_1$	$CO2_2$	$LNCO2_3$	$LNCO2_4$
	Equation 1	Equation 2	Equation 3	Equation 4
LNGFC	−0.017924 (−2.003947)**	−0.078960 (−8.438712)*	0.386476 (8.696548)*	0.276176 (3.267763)*
LNPA	0.006518 (1.269937)	0.058807 (10.96608)*	0.385719 (15.14447)*	0.441667 (9.765130)*
INF	0.009585 (5.696775)*	0.010952 (6.060711)*	0.084307 (9.823467)*	0.085941 (5.781938)*
FD	−0.000583 (−4.326209)*	−0.000365 (−2.575755)*	−0.006876 (−10.21203)*	0.000237 (0.216973)
ING	−0.000974 (−0.838049)	0.003406 (2.731077)*	0.004382 (0.739822)	0.047610 (4.579905)*
URBN (P-1)	0.063156 (7.022804)*	0.110611 (11.63963)*	0.461152 (10.21747)*	0.540366 (6.352633)*
RE*URBN (P-1)	−0.002212 (−7.848314)*	−0.003689 (−12.36635)*	−0.012996 (−9.172967)*	−0.013153 (−4.870441)*
Constant	0.682681 (3.451533)*	1.770206 (8.537654)*	−0.618735 (−0.628315)	−0.441037 (−0.236053)
R^2	0.145564	0.267070	0.739822	0.618362
Adjusted R^2	0.129178	0.253744	0.735092	0.610459
	Equation 5	Equation 6	Equation 7	Equation 8
LNGFC	0.020302 (3.501004)*	−0.065887 (−9.647492)*	0.573634 (12.90452)*	0.344254 (4.956489)*
LNPA	−0.013545 (−4.100575)*	0.033258 (8.538443)*	0.251256 (9.910530)*	0.405337 (10.34693)*
INF	0.008077 (6.914823)*	0.010642 (7.550450)*	0.095725 (10.43395)*	0.078689 (5.991964)*
FD	−0.000774 (−8.104028)*	−0.000139 (−1.219707)*	−0.004758 (−6.437473)*	−0.002744 (−2.495250)*
ING	−0.000976 (−1.271322)*	0.001585 (1.710905)***	0.015580 (2.583314)*	0.023503 (2.732800)*
URBN (P-2)	0.007509 (18.09688)*	0.004541 (9.210790)*	0.012423 (3.871006)*	0.014332 (5.297039)*
RE*URBN (P-2)	−0.000146 (−10.42011)*	−0.000227 (−13.69603)*	−0.000723 (−6.691980)*	−0.000780 (−5.512324)*
Constant	−0.205201 (−1.519531)	1.637487 (10.27516)*	−4.392918 (−4.235044)*	−1.393616 (−0.865477)
R^2	0.324187	0.238323	0.727133	0.583777
Adjusted R^2	0.311226	0.224474	0.722172	0.575157
	Equation 9	Equation 10	Equation 11	Equation 12
LNGFC	−0.036674 (−5.679948)*	−0.068611 (−10.17811)*	0.422370 (11.25799)*	0.145856 (2.337451)*
LNPA	−0.009589 (−2.745424)*	0.036513 (9.952912)*	0.238677 (11.68972)*	0.343672 (10.91788)*
INF	0.003912 (2.979436)*	0.010594 (7.506246)*	0.068867 (8.767158)*	0.061054 (5.146668)*
FD	−0.000239 (−2.381264)*	−0.000263 (−2.476701)*	−0.004301 (−7.289352)*	−0.000886 (−1.076658)
ING	−0.0513431 (−0.093686)*	0.001183 (1.350649)	0.008111 (1.664320)***	0.012275 (1.667924)***
URBN (P-3)	0.061172 (12.89370)*	0.011644 (2.333604)*	0.274863 (9.897948)*	0.296481 (6.976913)*
RE*URBN (P-3)	−0.000233 (−12.72610)*	−0.000301 (−15.59966)*	−0.001307 (−12.15149)*	−0.001770 (−10.51273)*
Constant	0.416007 (3.152198)*	1.605818 (11.53076)*	−4.263646 (−5.500937)*	−0.018036 (−0.014285)
R^2	0.319031	0.267260	0.718252	0.584553
Adjusted R^2	0.305972	0.253938	0.713129	0.575949

P-1, P-2, and P-3 specify proxy1, proxy 2 and proxy 3, respectively. T values are in parentheses.*, **, and *** indicating the level of significance at 1%, 5% and 10%, respectively

Table 4: Panel quantile regression

Independent Variables	$CO2_1$	$CO2_2$	$LNCO2_3$	$LNCO2_4$
	Equation 1	Equation 2	Equation 3	Equation 4
LNGFC	−0.050555 (−2.002902)**	−0.105872 (−5.900500)*	0.348894 (4.080176)*	0.245290 (2.151818)**
LNPA	0.052507 (2.515690)*	0.077216 (6.997213)*	0.424868 (8.573011)*	0.462622 (6.662968)*
INF	0.018882 (1.998332)**	0.009521 (2.122421)*	0.083006 (3.455098)*	0.091306 (3.832331)*
FD	−0.001053 (−3.831871)*	−0.000491 (−2.275310)*	−0.007757 (−7.999849)*	0.000513 (0.357638)
ING	0.001660 (0.775271)	0.004597 (1.999026)**	0.003213 (0.500360)	0.056461 (4.327499)*
URBN (P-1)	0.128401 (3.209923)*	0.136741 (7.231725)*	0.492037 (8.600464)*	0.518859 (3.611066)*
RE*URBN (P-1)	−0.003015 (−6.249270)*	−0.003630 (−10.21023)*	−0.013350 (−6.697479)*	−0.012112 (−3.349885)*
Constant	1.132425 (2.212802)**	2.312748 (5.970294)*	0.134864 (0.070833)	0.158708 (0.064221)
R^2	0.150950	0.247392	0.662324	0.502763
Adjusted R^2	0.134667	0.233708	0.656184	0.492465

(Contd...)

Table 4: ***(Continued)***

Independent Variables	$CO2_1$	$CO2_2$	$LNCO2_3$	$LNCO2_4$
	Equation 5	Equation 6	Equation 7	Equation 8
LNGFC	0.007984 (0.548879)	−0.082399 (−6.578887)*	0.616390 (9.676237)*	0.287619 (2.716914)*
LNPA	0.004631 (0.468004)	0.048335 (7.018456)*	0.207432 (6.337980)	0.449101 (7.860387)*
INF	0.021006 (2.836282)*	0.019306 (3.792739)*	0.111344 (6.301798)*	0.064021 (3.700845)*
FD	−0.000694 (−4.740347)*	−0.031937 (−0.312825)	−0.004931 (−5.772409)*	−0.003840 (−3.778944)*
ING	0.001745 (1.329794)	0.005138 (2.854371)*	0.015693 (2.080307)**	0.027536 (2.097983)**
URBN (P-2)	0.006260 (9.636367)*	0.004169 (6.893451)*	0.011661 (3.137913)*	0.012901 (4.792534)*
RE*URBN (P-2)	−0.000167 (−8.475707)*	−0.000244 (−12.12288)*	−0.000924 (−6.439235)*	−0.000926 (−2.865784)*
Constant	−0.035176 (−0.114383)	1.929979 (6.714031)*	−5.101059 (−3.388718)*	−0.047249 (−0.019035)
R^2	0.145069	0.225818	0.632852	0.523123
Adjusted R^2	0.128673	0.211742	0.626177	0.513247
	Equation 9	Equation 10	Equation 11	Equation 12
LNGFC	−0.040553 (−2.243290)*	−0.081252 (−6.735992)*	0.416319 (4.980968)*	0.198833 (2.344306)*
LNPA	0.009889 (0.892234)	0.047037 (7.989161)*	0.247396 (5.538024)*	0.343300 (6.222622)*
INF	0.015565 (1.769361)***	0.017116 (3.874379)*	0.074406 (3.221975)*	0.056288 (2.659165)*
FD	−0.000397 (−3.593394)*	−0.0676109 (−0.683669)	−0.003966 (−4.870925)*	−0.001261 (−1.442587)
ING	0.002372 (1.314336)	0.004335 (2.396639)*	0.009570 (1.558261)	0.030579 (2.434976)*
URBN (P-3)	0.056341 (8.796718)*	0.021080 (3.404588)*	0.317870 (4.073255)*	0.358835 (5.280764)*
RE*URBN (P-3)	−0.000274 (−8.166657)*	−0.000297 (−12.66156)*	−0.001292 (−11.79182)*	−0.001726 (−10.14955)*
Constant	0.440347 (1.221773)	1.675953 (6.588950)*	−4.867876 (−3.993837)*	−2.288749 (−1.495697)
R^2	0.188881	0.243769	0.681167	0.548416
Adjusted R^2	0.173325	0.230020	0.675370	0.539063

P-1, P-2, and P-3 specify proxy1, proxy 2 and proxy 3, respectively. T values are in parentheses.*, **, and *** indicating the level of significance at 1%, 5% and 10%, respectively

Quantile Regression are similar to those of the fixed effect model and robust least Square. In our empirical findings, like the fixed effect model and robust least square, LNGFC has an indecisive but significant impact on CO_2 omission. In our findings, patent application, inflation and industrial growth are positively and significantly associated with all substitutes for CO_2 emissions. Financial development is contrariwise and significantly associated with CO_2 radiations in almost all specifications of Panel Quantile Regression. In almost all specifications, the impact of all proxies of urbanization is positive and significant on CO_2 production. But the moderating impact of renewable energy on environmental depredation is inverse and significant.

5. DISCUSSION AND CONCLUSION

In this age of globalization, the migration of masses from rural to urban areas all over the developing economies is growing swiftly. This movement creates many opportunities as well as challenges for many. Among opportunities, better employments, medical facilities, education and lifestyle are essential. It is also a source of labor supply for the industrial and manufacturing sectors. Urbanization transforms economies from traditional agriculture to advanced and productive sectors by utilizing modern industrial and technical practices. On the other side, urbanization creates many socio-economic and environmental challenges for the economy and society. Rapid urbanization generates a dualistic economy and unbalanced growth among different segments of society. But at the same time, it has severely challenged the environment's quality. However, a counter-narrative against urbanization is that although bigger cities are venues of economic growth, they become a source of environmental degradation. The reason for this is a decrease in forestation and CO_2 emissions and the setting up of more buildings and factories.

Many developing and developed countries are severely facing the issue of environmental quality as an effect of energy consumption. One of the most significant contributions to CO_2 emissions is fossil fuel energy. CO_2 emissions have grown due to using oil and fossil fuels to achieve high growth rates through industrialization. Natural resource depletion and rising demand for traditional energy sources have prompted policymakers to look for alternative energy sources. The consumption of energy is directly associated with the emissions of carbon dioxide.Nonrenewable energy sources such as coal and petroleum lead to the deterioration of the environment. Mitigating CO_2 emissions has become a global policy priority due to environmental concerns. Environmental preservation has been given top priority by the Sustainable Development Goals (SDGs). Clean and renewable energy is a key component of SDG 7 for a sustainable environment and economic development. So, this study investigated the moderating role of renewable energy consumption in the urbanization- CO_2 nexus. Twenty-three highly urbanized economies of the world were selected for the period 1997 to 2021. Three econometrics techniques are applied for empirical investigation: fixed effect model, robust least square and panel quantile regression with twelve specifications. The dependent variable is carbon dioxide (CO_2) emissions. It is measured by four proxies, i.e., CO_2 emissions (kg per 2015 US$ of GDP) ($CO2_1$), CO_2 emissions (kg per PPP $ of GDP) ($CO2_2$), natural log of CO_2 emissions (kt) ($LNCO2_3$) and the natural log of CO_2 emissions from solid fuel consumption (kt) ($LNCO2_4$). Explanatory variables are gross fixed capital formation, patent application, inflation, financial development (F.D.), industrial growth, urbanization and interaction term of renewable energy and urbanization. Three alternatives measure urbanization (URBN), i.e., Urban population growth (annual %) is used by 1-4 specification, Population in the largest city (% of urban population) is used by 5-6 specification, and the natural log of Population in largest city is used by 9-12 specification. In our empirical findings, gross fixed capital has an inconclusive impact on CO_2 omission in all econometric techniques. Investment or capital stock may increase or decreases the level of CO_2 production depending upon the consumption of the type of energy and environment policy. Chi-Chuan (2022) evaluates the influence of urbanization on environmental quality in China from 1996–2018 by using the dynamic panel threshold technique and taking the moderating role of FDI into account. The findings imply that when urbanization picks up speed, CO_2 emissions also grow. However, this negative impact lessens as foreign capital levels rise. Mahmood (2022) shows that considering investment and foreign direct investment (FDI), exports, and imports may positively impact environmental degradation. Like Kahia et al. (2021), Saudi Arabia's capital stock and CO_2 output were positively correlated. Parveen et al. (2021) found an inverse association between investment and CO_2 production in Pakistan. While Hassan (2018) considered the case study of Malaysia from1976-2013 and found a positive link between investment and CO_2 production.

In our findings, patent applications or innovations positively affect all CO_2 emissions. Our findings are also supported by earlier literature, as Gierałtowska et al. (2022) found that innovation, peroxided by residents' patents, positively affects CO_2 radiations. In South Asian economies, Mughal et al. (2022) discovered a direct correlation between technical innovation and environmental deterioration. Technological innovation has been crucial to the socioeconomic growth of societies, but this growth has also brought with it certain possible environmental hazards (Shaari et al. 2016; Ullah et al. 2021). Our findings concur with those of Balin and Akan (2015), Su and Moaniba (2017) and Garrone and Grilli (2010). Inflation and industrial growth are positively and significantly associated with all proxies of CO_2 emissions. Industrial growth is positively allied with environmental deprivation conferring to Ahmed et al. (2022), Gierałtowska et al. (2022) and Rani (2022). While financial development is inversely and significantly associated with CO_2 emissions. Our results are also supported by previous literature. Like, Mushtaq and Ahmed (2021) found that financial development had played moderating influence in improving environmental quality in OECD economies. Rani (2022) specified that financial development is a source to mitigate carbon emissions in south Asian economies. Amin et al. (2022) discovered that financial development and renewable energy use harm CO_2 emissions. However, urbanization and foreign direct investment lead to environmental deterioration. Ruza and Caro-Carretero (2022) argue that in the G7 economies, the relationship between financial progress and environmental sustainability is statistically significant and monotonically positive. Similarly, Khan et al. (2022) demonstrate a significant and positive association between financial development and environmental sustainability using panel data on 15 emerging and growth-leading economies from 1984 to 2018. In the fixed effect model, robust least square and panel quantile regression, the impact of all proxies of urbanization is positive and significant on CO_2 production. Our results are similar to the previous findings of Parikh and Shukla, 1995; Cole and Neumayer, 2004; York, 2007; Elheddad et al., 2020; Abbasi et al., 2020; Rehman et al., 2021). But the moderating impact of renewable energy on environmental depredation is inverse and significant. Akadiri et al. (2019), Dong et al. (2019), Usman et al. (2020), Djellouli et al. (2022), Murshed et al. (2022), Gieratowska (2022) and Yang et al. (2022) also found that renewable energy played the crucial and strategic role in developing eco-friendly eminence.

In this age of modernization, it is impossible to limit the continuity of urbanization. Since it provides many opportunities in the form of better employment, medical facilities, education and life style etc. This massive burden of urbanization damages the quality of the environment. So the question is how we can address its adverse effects. In this regard, one possible strategy is renewable energy consumption rather than nonrenewable because traditional energy sources used in industry and business harm the environment. However, the utilization of clean energy and environmentally friendly technology in both domestic and international arenas is receiving more attention from environmentalists, international organizations, and governments. Nonrenewable energy sources such as coal and petroleum lead to the deterioration of the environment (Ahmadov and van der Borg, 2019). Consequently, renewable (biomass, hydro, wind, solar and nuclear) energy should be considered a feasible alternative for raising the energy supply while reducing CO_2 emissions. (Menyah and Wolde-Rufael, 2010; Sinha et al., 2017; Pata, 2018).

5.1. Recommendations

Based on empirical and econometric exploration, our study recommends three major policy options to address the urbanization-CO_2 nexus. Firstly, industrialization should be well-ordered in urban zones to improve ecofriendly excellence. Secondly, financial development should be increased since it has a positive and significant impact on an environmental eminence. Last but not least, renewable energy consumption should be enhanced in urban areas to mitigate CO_2 production.

5.2. Future Research

In the CO_2 Urbanization nexus, we can see the moderating role of other socio-economic and environmental indicators such as human capital, FDI, governance, environmental policy and institutions. Further, this study can be generalized to developing and African economies.

REFERENCES

Abbasi, M.A., Parveen, S., Khan, S., Kamal, M.A. (2020), Urbanization and energy consumption effects on carbon dioxide emissions: Evidence from Asian-8 countries using panel data analysis. Environmental Science and Pollution Research, 27(15), 18029-18043.

Adams, S., Boateng, E., Acheampong, A.O. (2020), Transport energy consumption and environmental quality: Does urbanization matter? Science of the Total Environment, 744, 140617.

Adedoyin, F.F., Ozturk, I., Agboola, M.O., Agboola, P.O., Bekun, F.V. (2021), The implications of renewable and nonrenewable energy generating in Sub-Saharan Africa: The role of economic policy uncertainties. Energy Policy, 150, 112115.

Adusah-Poku, F. (2016), Carbon dioxide emissions, urbanization and Population: Empirical evidence from Sub-Sahran Africa. Energy Economics Letters, 3(1), 1-16.

Aguir Bargaoui, S. (2021), Renewable energies and energy efficiency adoption's impact on the environmental quality of middle east North Africa Countries. Journal of Applied Economic Sciences,

16(3), 361-373.
Ahmad, A., Zhao, Y., Shahbaz, M., Bano, S., Zhang, Z., Wang, S., Liu, Y. (2016), Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. Energy Policy, 96, 131-143.
Ahmad, M., Zhao, Z.Y., Li, H. (2019), Revealing stylized empirical interactions among construction sector, urbanization, energy consumption, economic growth and CO_2 emissions in China. Science of the Total Environment, 657, 1085-1098.
Ahmadov, A.K., van der Borg, C. (2019), Do natural resources impede renewable energy production in the E.U.? A mixed-methods analysis. Energy Policy, 126, 361-369.
Ahmed, F., Ali, I., Kousar, S., Ahmed, S. (2022), The environmental impact of industrialization and foreign direct investment: Empirical evidence from Asia-Pacific region. Environmental Science and Pollution Research, 29(20), 29778-29792.
Akadiri, S.S., Alola, A.A., Akadiri, A.C., Alola, U.V. (2019), Renewable energy consumption in EU-28 countries: Policy toward pollution mitigation and economic sustainability. Energy Policy, 132, 803-810.
Alam, S., Fatima, A., Butt, M.S. (2007), Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation. Journal of Asian Economics, 18(5), 825-837.
Ali, R., Bakhsh, K., Yasin, M.A. (2019), Impact of urbanization on CO_2 emissions in emerging economy: Evidence from Pakistan. Sustainable Cities and Society, 48, 101553.
Ali, S., Anwar, S., Nasreen, S. (2017), Renewable and nonrenewable energy and its impact on environmental quality in South Asian Countries. Forman Journal of Economic Studies, 13, 177-194.
Allard, A., Takman, J., Uddin, G.S., Ahmed, A. (2018), The N-shaped environmental Kuznets curve: An empirical evaluation using a panel quantile regression approach. Environmental Science and Pollution Research, 25(6), 5848-5861.
Al-Mulali, U., Fereidouni, H.G., Lee, J.Y., Sab, C.N.B.C. (2013), Exploring the relationship between urbanization, energy consumption, and CO_2 emission in MENA countries. Renewable and Sustainable Energy Reviews, 23, 107-112.
Amin, A., Ameer, W., Yousaf, H., Akbar, M. (2022). Financial development, institutional quality, and the influence of various environmental factors on carbon dioxide emissions: Exploring the nexus in China. Frontiers in Environmental Science, 9, 838714.
Apergis, N., Payne, J.E. (2014), Renewable energy, output, CO_2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. Energy Economics, 42, 226-232.
Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y. (2010), On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecological Economics, 69(11), 2255-2260.
Asumadu-Sarkodie, S., Owusu, P.A. (2017), A multivariate analysis of carbon dioxide emissions, electricity consumption, economic growth, financial development, industrialization, and urbanization in Senegal. Energy Sources, Part B: Economics, Planning, and Policy, 12(1), 77-84.
Azam, M., Khan, A.Q. (2016), Urbanization and environmental degradation: Evidence from four SAARC countries-Bangladesh, India, Pakistan, and Sri Lanka. Environmental Progress and Sustainable Energy, 35(3), 823-832.
Baek, J. (2016), Do nuclear and renewable energy improve the environment? Empirical evidence from the United States. Ecological Indicators, 66, 352-356.
Balin, B.E., Akan, D.M. (2015), EKC hypothesis and the effect of innovation: A panel data analysis. Journal of Business Economics and Finance, 4(1), 81-91.
Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S. (2018), How economic growth, renewable electricity and natural resources contribute to CO_2 emissions? Energy Policy, 113, 356-367.
Bekhet, H.A., Othman, N.S. (2017), Impact of urbanization growth on Malaysia CO_2 emissions: Evidence from the dynamic relationship. Journal of Cleaner Production, 154, 374-388.
Bekun, F.V., Alola, A.A., Sarkodie, S.A. (2019), Toward a sustainable environment: Nexus between CO_2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of the Total Environment, 657, 1023-1029.
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.
Brantley, B., Liddle, S. (2014), Might electricity consumption cause urbanization instead? Evidence from heterogeneous panel long-run causality tests. Global Environmental Change, 24, 42-51.
Canay, I.A. (2011), A simple approach to quantile regression for panel data. The Econometrics Journal, 14(3), 368-386.
Çetin, M., Ecevit, E. (2015), Urbanization, energy consumption and CO_2 emissions in Sub-Saharan countries: A panel co-integration and causality analysis. Journal of Economics and Development Studies, 3(2), 66-76.
Chang, R.D., Zuo, J., Zhao, Z.Y., Zillante, G., Gan, X.L., Soebarto, V. (2017), Evolving theories of sustainability and firms: History, future directions and implications for renewable energy research. Renewable and Sustainable Energy Reviews, 72, 48-56.
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.
Chen, M., Zhang, H., Liu, W., Zhang, W. (2014), The global pattern of urbanization and economic growth: Evidence from the last three decades. PLoS One, 9(8), e103799.
Cherni, A., Jouini, S.E. (2017), An ARDL approach to the CO_2 emissions, renewable energy and economic growth nexus: Tunisian evidence. International Journal of Hydrogen Energy, 42(48), 29056-29066.
Chi-Chuan, L., Boxu, Z., Tsung-Yu, Y., Chin-Hsien, Y., Jinsong, Z. (2022), The impact of urbanization on CO_2 emissions in China: The key role of foreign direct investment. Emerging Markets Finance and Trade, 59, 451-462.
Chowdhury, H., Chowdhury, T., Thirugnanasambandam, M., Farhan, M., Ahamed, J.U., Saidur, R., Sait, S.M. (2019), A study on exergetic efficiency vis-à-vis sustainability of industrial sector in Bangladesh. Journal of Cleaner Production, 231, 297-306.
Cole, M.A., Neumayer, E. (2004), Examining the impact of demographic factors on air pollution. Population and Environment, 26(1), 5-21.
Destek, M.A., Aslan, A. (2020), Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries. Renewable Energy, 151, 1298-1306.
Destek, M.A., Sinha, A. (2020), Renewable, nonrenewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries. Journal of Cleaner Production, 242, 118537.
Dhami, J.K., Singh, H., Gupta, M. (2013), Industrialization at the cost of environment degradation-a case of leather and iron and steel industry from Punjab economy. Innovative Journal of Business and Management, 2(1), 19-21.
Djellouli, N., Abdelli, L., Elheddad, M., Ahmed, R., Mahmood, H. (2022), The effects of nonrenewable energy, renewable energy, economic growth, and foreign direct investment on the sustainability of African countries. Renewable Energy, 183, 676-686.
Dogan, E., Turkekul, B. (2016), CO_2 emissions, real output, energy

consumption, trade, ur-banization and financial development: Testing the EKC hypothesis for the USA. Environmental Science and Pollution Research, 23, 1203-1213.

Dong, K., Dong, X., Dong, C. (2019), Determinants of the global and regional CO_2 emissions: What causes what and where? Applied Economics, 51(46), 5031-5044.

Dong, K., Sun, R., Hochman, G. (2017), Do natural gas and renewable energy consumption lead to less CO_2 emission? Empirical evidence from a panel of BRICS countries. Energy, 141, 1466-1478.

Du, G., Lin, W., Sun, C., Zhang, D. (2015), Residential electricity consumption after the reform of tiered pricing for household electricity in China. Applied Energy, 157, 276-283.

Ehrhardt-Martinez, K., Crenshaw, E.M., Jenkins, J.C. (2002), Deforestation and the environmental Kuznets curve: A cross-national investigation of intervening mechanisms. Social Science Quarterly, 83(1), 226-243.

Elheddad, M., Djellouli, N., Tiwari, A.K., Hammoudeh, S. (2020), The relationship between energy consumption and fiscal decentralization and the importance of urbanization: Evidence from Chinese provinces. Journal of Environmental Management, 264, 110474.

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

Feng, R., Zheng, H.J., Zhang, A.R., Huang, C., Gao, H., Ma, Y.C. (2019), Unveiling tropospheric ozone by the traditional atmospheric model and machine learning, and their comparison: A case study in hangzhou, China. Environmental Pollution, 252, 366-378.

Garrone, P., Grilli, L. (2010), Is there a relationship between public expenditures in energy R&D and carbon emissions per GDP? An empirical investigation. Energy Policy, 38(10), 5600-5613.

Gasimli, O., Naradda Gamage, S.K., Shihadeh, F., Rajapakshe, P.S.K., Shafiq, M. (2019), Energy, trade, urbanization and environmental degradation nexus in Sri Lanka: Bounds testing approach. Energies, 12(9), 1655.

Gierałtowska, U., Asyngier, R., Nakonieczny, J., Salahodjaev, R. (2022), Renewable energy, urbanization, and CO_2 emissions: A global test. Energies, 15(9), 1-13.

Graham, B.S., Hahn, J., Poirier, A., Powell, J.L. (2015), Quantile regression with panel data (No. w21034). Cambridge: National Bureau of Economic Research.

Grimm, N.B., Foster, D., Groffman, P., Grove, J.M., Hopkinson, C.S., Nadelhoffer, K.J., & Peters, D.P. (2008), The changing landscape: Ecosystem responses to urbanization and pollution across climatic and societal gradients. Frontiers in Ecology and the Environment, 6(5), 264-272.

Grodzicki, T., Jankiewicz, M. (2022), The impact of renewable energy and urbanization on CO_2 emissions in Europe-Spatio-temporal approach. Environmental Development, 44, 100755.

Gu, J., Volgushev, S. (2019), Panel data quantile regression with grouped fixed effects. Journal of Econometrics, 213(1), 68-91.

Guzel, A.E., Arslan, U., Acaravci, A. (2021), The impact of economic, social, and political globalization and democracy on life expectancy in low-income countries: Are sustainable development goals contradictory? Environment, Development and Sustainability, 23(9), 13508-13525.

Hanif, I. (2017), Economics-energy-environment nexus in Latin America and the Caribbean. Energy, 141, 170-178.

Hanif, I. (2018), Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: A panel investigation. Energy Strategy Reviews, 21, 16-24.

Hassan, S. (2018), Dynamic impact of energy consumption, private investment and financial development on environmental pollutions: Evidence from Malaysia. International Journal of Energy Economics and Policy, 8(4), 63-69.

Hausman, J.A. (1978), Specification tests in econometrics. Econometrica: Journal of the Econometric Society, 46, 1251-1271.

Ho, K., Naugher, J. (2000), Outliers lie an illustrative example of identifying outliers and applying robust models. Multiple Linear Regression Viewpoints, 26(2), 2-6.

Hope, K.R. (1998), Urbanization and urban growth in Africa. Journal of Asian and African Studies, 33, 345-358.

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.

Hossain, S. (2012), An econometric analysis for CO_2 emissions, energy consumption, economic growth, foreign trade and urbanization of Japan. Low Carbon Economy, 3, 92-105.

Iorember, P.T., Goshit, G.G., Dabwor, D.T. (2020), Testing the nexus between renewable energy consumption and environmental quality in Nigeria: The role of broad-based financial development. African Development Review, 32(2), 163-175.

Kahia, M., Omri, A., Jarraya, B. (2021), Green energy, economic growth and environmental quality nexus in Saudi Arabia. Sustainability, 13(3), 1-13.

Karsenty, A., Blanco, C., Dufour, T. (2003), Forest and Climate Change: Instruments Related to the United Nations Framework Convention on Climate Change and their Potential for Sustainable Forest Management in Africa. Rome: FAO.

Kashem, M.A., Rahman, M.M. (2019), CO_2 emissions and development indicators: A causality analysis for Bangladesh. Environmental Processes, 6(2), 433-455.

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

Kayani, U. N., Mumtaz, R., Fahlevi, M., Nasseseredine , H., and Hadinata, A. (2024). Unbridling the economic growth and environmental nexus in Pakistan. International Journal of Energy Economics and Policy, 14(1), 488-495.

Khan, M.A., Khan, M.A., Ahmed, M., Khan, K. (2022), Environmental consequences of financial development in emerging and growth-leading economies: A multidimensional assessment. Borsa Istanbul Review, 22(4), 668-677.

Kirikkaleli, D., Kalmaz, D.B. (2020), Testing the moderating role of urbanization on the environmental Kuznets curve: Empirical evidence from an emerging market. Environmental Science and Pollution Research, 27(30), 38169-38180.

Li, K., Lin, B. (2015), Impacts of urbanization and industrialization on energy consumption/CO_2 emissions: Does the level of development matter? Renewable and Sustainable Energy Reviews, 52, 1107-1122.

Liddle, B. (2004), Demographic dynamics and per capita environmental impact: Using panel regressions and household decompositions to examine Population and transport. Population and Environment, 26(1), 23-39.

Liddle, B. (2014), Impact of Population, age structure, and urbanization on carbon emissions/energy consumption: Evidence from macro-level, cross-country analyses. Population and Environment, 35(3), 286-304.

Liddle, B., Lung, S. (2010), Age-structure, urbanization, and climate change in developed countries: revisiting STIRPAT for disaggregated Population and consumption-related environmental impacts. Population and Environment, 31(5), 317-343.

Lin, B.Q., Liu, X.Y. (2010), China's carbon dioxide emissions under the urbanization process: Influence factors and abatement policies. Economic Research Journal, 45, 66-78.

Liu, X., Zhang, S., Bae, J. (2017), The nexus of renewable energy-agriculture-environment in BRICS. Applied Energy, 204, 489-496.

Mahmood, H. (2022), The spatial analyses of consumption-based CO_2

emissions, exports, imports, and FDI nexus in GCC countries. Environmental Science and Pollution Research, 29, 48301-48311.

Malik, N., Asmi, F., Ali, M., Rahman, M.M. (2017), Major factors leading rapid urbanization in China and Pakistan: A comparative study. Journal of Social Science Studies, 5(1), 148.

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

Menyah, K., Wolde-Rufael, Y. (2010), CO_2 emissions, nuclear energy, renewable energy and economic growth in the U.S. Energy Policy, 38(6), 2911-2915.

Mert, M., Bölük, G. (2016), Do foreign direct investment and renewable energy consumption affect the CO_2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries. Environmental Science and Pollution Research, 23(21), 21669-21681.

Mughal, N., Arif, A., Jain, V., Chupradit, S., Shabbir, M.S., Ramos-Meza, C.S., Zhanbayev, R. (2022), The role of technological innovation in environmental pollution, energy consumption and sustainable economic growth: Evidence from South Asian economies. Energy Strategy Reviews, 39, 100745.

Murshed, M., Nurmakhanova, M., Al-Tal, R., Mahmood, H., Elheddad, M., Ahmed, R. (2022), Can intra-regional trade, renewable energy use, foreign direct investments, and economic growth mitigate ecological footprints in South Asia? Energy Sources, Part B: Economics, Planning, and Policy, 17(1), 1-26.

Mushtaq, M., Ahmed, S. (2021), Environmental Kuznets Curve: Moderating role of financial development. Economic Journal of Emerging Markets, 13(1), 27-40.

Nathaniel, S., Khan, S.A.R. (2020), The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries. Journal of Cleaner Production, 272, 122709.

Nathaniel, S.P., Yalçiner, K., Bekun, F.V. (2021), Assessing the environmental sustainability corridor: Linking natural resources, renewable energy, human capital, and ecological footprint in BRICS. Resources Policy, 70, 101924.

Nguyen, C.T., Nguyen, D.T.H., Phan, D.K. (2021), Factors affecting urban electricity consumption: A case study in the Bangkok Metropolitan Area using an integrated approach of earth observation data and data analysis. Environmental Science and Pollution Research, 28(10), 12056-12066.

Niu, H.L. (2019), An empirical test of China's urbanization carbon emission effect. Statistical Decision, 35, 138-142.

Ozturk, M., Yuksel, Y.E. (2016), Energy structure of Turkey for sustainable development. Renewable and Sustainable Energy Reviews, 53, 1259-1272.

Paramati, S.R., Sinha, A., Dogan, E.V. (2017), The significance of renewable energy use for economic output and environmental protection: Evidence from the Next 11 developing economies. Environmental Science and Pollution Research, 24, 13546-13560.

Parikh, J., Shukla, V. (1995), Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries. Global Environmental Change, 5(2), 87-103.

Parveen, S., Sadiqa, B.A., Ali, S., Yasmin, F. (2021), Impact of private investment, economic growth and financial development on environmental degradation: Evidence from Pakistan. Review of Economics and Development Studies, 7(1), 13-24.

Pata, U.K. (2018), Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: Testing EKC hypothesis with structural breaks. Journal of Cleaner Production, 187, 770-779.

Pickett, S.T.A., Boone, C., McGrath, B.P., Cadenasso, M.L., Childers, D.L., Ogden, L.A., McHale, M., Morgan Grove, J. (2013), Ecological science and transformation to the sustainable city. Cities, 32(1), 10-20.

Poumanyvong, P., Kaneko, S. (2010), Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. Ecological Economics, 70(2), 434-444.

Pugh, C. (1995), Urbanization in developing countries: An overview of the economic and policy issues in the 1990s. Cities, 12(6), 381-398.

Rafiq, S., Salim, R., Nielsen, I. (2016), Urbanization, openness, emissions, and energy intensity: A study of increasingly urbanized emerging economies. Energy Economics, 56, 20-28.

Raheem, I.D., Ogebe, J.O. (2017), CO_2 emissions, urbanization and industrialization: Evidence from a direct and indirect heterogeneous panel analysis. Management of Environmental Quality: An International Journal, 28(6), 851-867.

Rahman, M.M., Vu, X.B. (2020), The nexus between renewable energy, economic growth, trade, urbanisation and environmental quality: A comparative study for Australia and Canada. Renewable Energy, 155, 617-627.

Rani, T., Amjad, M.A., Asghar, N., Rehman, H.U. (2022), Revisiting the environmental impact of financial development on economic growth and carbon emissions: Evidence from South Asian economies. Clean Technologies and Environmental Policy, 24(9), 2957-2965.

Rayhan, I., Islam, M.S. (2015), Dynamic causality between urbanization and environmental degradation in Bangladesh: Evidence from ARDL bounds testing approach. The Jahangirnagar Review, Part II: Social Sciences, 2015, 105-117.

Reddy, B.S., Assenza, G.B. (2009), The great climate debate. Energy Policy, 37(8), 2997-3008.

Rehman, A., Ma, H., Chishti, M.Z., Ozturk, I., Irfan, M., Ahmad, M. (2021), Asymmetric investigation to track the effect of urbanization, energy utilization, fossil fuel energy and CO_2 emission on economic efficiency in China: Another outlook. Environmental Science and Pollution Research, 28(14), 17319-17330.

Riti, J.S., Shu, Y. (2016), Renewable energy, energy efficiency, and eco-friendly environment (R-E5) in Nigeria. Energy, Sustainability and Society, 6(1), 1-16.

Rousseeuw, P., Yohai, V. (1984), Robust regression by means of S-estimators. In: Robust and Nonlinear Time Series Analysis. New York: Springer. p. 256-272.

Ruza, C., Caro-Carretero, R. (2022), The nonlinear impact of financial development on environmental quality and sustainability: Evidence from G7 countries. International Journal of Environmental Research and Public Health, 19(14), 8382.

Sadorsky, P. (2009), Renewable energy consumption, CO_2 emissions and oil prices in the G7 countries. Energy Economics, 31(3), 456-462.

Sadorsky, P. (2014), The effect of urbanization on CO_2 emissions in emerging economies. Energy Economics, 41, 147-153.

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.

Shaari, M.S., Abdullah, D.N.C., Alias, N.S.B., Adnan, N.S.M. (2016), Positive and negative effects of research and development. International Journal of Energy Economics and Policy, 6(4), 767-770.

Shahbaz, M., Khraief, N., Uddin, G.S., Ozturk, I. (2014), Environmental Kuznets curve in an open economy: A bounds testing and causality analysis for Tunisia. Renewable and Sustainable Energy Reviews, 34, 325-336.

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

Sharif, A., Baris-Tuzemen, O., Uzuner, G., Ozturk, I., Sinha, A. (2020), Revisiting the role of renewable and nonrenewable energy consumption on Turkey's ecological footprint: Evidence from Quantile ARDL approach. Sustainable Cities and Society, 57, 102138.

Sharma, S.S. (2011), Determinants of carbon dioxide emissions: Empirical evidence from 69 countries. Applied Energy, 88(1), 376-382.

Sheehy, B., Farneti, F. (2021), Corporate social responsibility, sustainability, sustainable development and corporate sustainability: What is the difference, and does it matter? Sustainability, 13(11), 5965.

Shi, F.F., Wang, H., Guo, M.Y. (2017), The study of urbanization ratio of different urbanization developing zone in China on carbon emission. Journal Gansu Science, 29, 148-152.

Silva, S., Soares, I., Pinho, C. (2012), The impact of renewable energy sources on economic growth and CO_2 emissions: A SVAR approach. European Research Studies, Special Issue on Energy, 15(1), 133-144.

Sinha, A., Shahbaz, M., Balsalobre, D. (2017), Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. Journal of Cleaner Production, 168, 1217-1229.

Sohag, K., Al Mamun, M., Uddin, G.S., Ahmed, A.M. (2017), Sectoral output, energy use, and CO_2 emission in middle-income countries. Environmental Science and Pollution Research, 24(10), 9754-9764.

Staudte, R.G., Sheather, S.J. (1990), Robust Estimation and Testing. New York: John Wiley Sons. Inc.

Strielkowski, W., Tarkhanova, E., Baburina, N., Streimikis, J. (2021), Corporate social responsibility and the renewable energy development in the Baltic States. Sustainability, 13(17), 9860.

Su, H.N., Moaniba, I.M. (2017), Does innovation respond to climate change? Empirical evidence from patents and greenhouse gas emissions. Technological Forecasting and Social Change, 122, 49-62.

Toklu, E. (2013), Overview of potential and utilization of renewable energy sources in Turkey. Renewable Energy, 50, 456-463.

Topcu, B.A. (2021), The impact of export, import, and renewable energy consumption on Turkey's ecological footprint. Journal of Economics Finance and Accounting, 8(1), 31-38.

Ullah, S., Ozturk, I., Majeed, M.T., Ahmad, W. (2021), Do technological innovations have symmetric or asymmetric effects on environmental quality? Evidence from Pakistan. Journal of Cleaner Production, 316, 128239.

Usman, A., Ullah, S., Ozturk, I., Chishti, M.Z., Zafar, S.M. (2020), Analysis of asymmetries in the nexus among clean energy and environmental quality in Pakistan. Environmental Science and Pollution Research, 27(17), 20736-20747.

Wang, J., Dong, K. (2019), What drives environmental degradation? Evidence from 14 Sub-Saharan African countries. Science of the Total Environment, 656, 165-173.

Wang, N., Zhu, H., Guo, Y., Peng, C. (2018), The heterogeneous effect of democracy, political globalisation, and urbanisation on PM2.5 concentrations in G20 countries: Evidence from panel quantile regression. Journal of Cleaner Production, 194, 54-68.

Wang, Q., Wang, L. (2021), The nonlinear effects of population aging, industrial structure, and urbanization on carbon emissions: A panel threshold regression analysis of 137 countries. Journal of Cleaner Production, 287, 125381.

Wang, R., Mirza, N., Vasbieva, D.G., Abbas, Q., Xiong, D. (2020), The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP 21 Agreements? Journal of Environmental Management, 271, 111027.

Wang, Y., Chen, L., Kubota, J. (2016), 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., Li, L., Kubota, J., Han, R., Zhu, X., Lu, G. (2016), Does urbanization lead to more carbon emission? Evidence from a panel of BRICS countries. Applied Energy, 168, 375-380.

Xu, Q., Dong, Y.X., Yang, R. (2018), Urbanization impact on carbon emissions in the Pearl River Delta region: Kuznets curve relationships. Journal of Cleaner Production, 180, 514-523.

Xu, Y., Zhou, S.F. (2011), An empirical study on urbanization and CO_2 emissions in china. Resources and Environment in the Yangtze Basin, 20(11), 1304-1309.

Xuemei, B., Jin, C., Peijun, S. (2012), Landscape urbanization and economic growth in China: Positive feed backs and sustainability dilemmas. Environmental Science and Technology, 46(1), 132-139.

Yang, Q., Huo, J., Saqib, N., Mahmood, H. (2022), Modelling the effect of renewable energy and public-private partnership in testing EKC hypothesis: Evidence from methods moment of quantile regression. Renewable Energy, 192, 485-494.

Yazdi, S.K., Dariani, A.G. (2019), CO_2 emissions, urbanization and economic growth: Evidence from Asian countries. Economic Research-Ekonomska Istraživanja, 32(1), 510-530.

Yi, Y., Ma, S., Guan, W., Li, K. (2017), An empirical study on the relationship between urban spatial form and CO_2 in Chinese cities. Sustainability, 9(4), 672.

York, R. (2007), Demographic trends and energy consumption in European Union Nations, 1960–2025. Social Science Research, 36(3), 855-872.

York, R., Rosa, E.A., Dietz, T. (2003), STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. Ecological Economics, 46(3), 351-365.

Zafar, M.W., Shahbaz, M., Sinha, A., Sengupta, T., Qin, Q. (2020), How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. Journal of Cleaner Production, 268, 122149.

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.

Zhang, N., Yu, K., Chen, Z. (2017), How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. Energy Policy, 107, 678-687.

Zhao, J., Chen, S., Jiang, B., Ren, Y., Wang, H., Vause, J., Yu, H. (2013), Temporal trend of green space coverage in China and its relationship with urbanization over the last two decades. Science of the Total Environment, 442, 455-465.

Zhu, Q., Peng, X. (2012), The impacts of population change on carbon emissions in China during 1978–2008. Environmental Impact Assessment Review, 36, 1-8.