Bulletin of Business and Economics, 12(4), 372-386
https://bbejournal.com
https://doi.org/10.61506/01.00136

Urbanization, Energy Consumption and Environmental Quality in Asian Countries

Insha Kunwal[1], Muhammad Ramzan Sheikh[2], Muhammad Zahir Faridi[3], Muhammad Imran Mushtaq[4]

Abstract
The rate of urbanization has enhanced around the globe. By moving the production from less to more energy-intensive sources, increasing the rate of urbanization leads to more energy consumption. The major threat to the environment of the world is the increasing rate of greenhouse gas emissions and global warming. The main purpose of this study is to elaborate on the relationship between urbanization, energy consumption, and CO_2 emission in Asian countries. In this study, CO_2 is used as a dependent variable while urban population, population density, renewable and non-renewable energy consumption, GDP per capita growth, the square of GDP per capita growth, and trade are used as the independent variables. We have obtained data from 1980 to 2020 from 32 Asian countries. Data have been taken from the sources of the Energy Information Administration (EIA) and World Development Indicators (WDI). We have used the panel ARDL technique for the long-run and short-run estimation of variables. The findings of this study reveal that non-renewable energy has a positive but insignificant whereas per capita GDP growth, urban population, population density, and trade have a positive effect; and per capita square of GDP growth and renewable energy consumption has a negative and significant effect on CO_2 emission. The findings of Granger causality show that there is uni-variate causality running from non-renewable energy consumption towards CO_2 emission and from urban population to renewable energy. There is bi-variate causality running from renewable energy to CO_2, non-renewable to renewable energy consumption, and from urban population to non-renewable energy consumption. There is no causality exists between the urban population and CO_2 emission. This study suggests that the Government may adopt more energy conservation policies to reduce CO_2 emissions. The government may suggest using the public transportation system rather than the private transportation system to mitigate CO_2 emissions.
Keywords: Environmental degradation, Urban population, Renewable energy consumption, Trade

1. Introduction
Urbanization is an interrelated process of economic, technological, political, cultural, social, and environmental changes which involve the compactness of economic and population activities in urban areas through land-use change. On the other hand, urbanization is the physical growth of cities like the extension of population size and urbanized regions (Chikaraishi et al. 2013). The urbanization rate has increased quickly around the world. In the twenty-first century, it has become one of the largest features of economic development. Urbanization is coming about at an unparalleled scale and speed in developing countries. A United Nation report expose that more than 54% of the world's population live in urban areas in 2014 which is expected to increase by 66% by 2050. The rapid urbanization of Asia has guided public safety and economic development, increasing the use of energy which has an unfavourable effect on the climate condition and air quality. By facilitating the absorption and release of carbon in the atmosphere, urbanization has both positive and negative effects on the environment. Urbanization stimulates fossil fuel burning and higher use of energy through industrialization (Ali and Audi, 2016; Salim et al. 2017).
The enhancement of greenhouse gas emissions and global warming has a major threat to the environment of the globe. The major greenhouse gases are methane, water vapour, nitrous oxide, carbon dioxide emission, sulfur dioxide, and chlorofluorocarbon. An important driver of global climate change is carbon dioxide emissions which are associated with different economic activities. Greenhouse gas emissions caused by energy use and the increasing energy demand accelerate economic growth. The increase in CO_2 emissions and energy use is another situation capturing the increase in per capita GDP and urbanization. (Lu, 2017). Ambient quality is the pollutant's quantity in the environment for example; the concentration of chemicals in the lake's waters. Outdoor or ambient air pollution consists of a complex mixture of gases, liquid, and particulate matter. Indoor air pollution is more contaminated than ambient air. Indoor air pollutants such as carbon monoxide, nitrogen dioxide, wood smoke, environmental tobacco smoke, allergens, and other biological contaminants can cause nausea and fatigue, directly and indirectly, health hazards, and headaches. Global warming is a most important problem for the environment which comes from the use of resources with fossil fuels to fulfil the need for energy (Field and Field, 2003; Ali et al., 2021).
Energy is the key source for our society and it is the necessary material basis of social and economic development. The main cause of global warming and environmental degradation are energy-related greenhouse gas emissions from the use of non-renewable sources of energy. Many environmental problems such as biodiversity, greenhouse emissions, ecological deficit, and ecological footprint issues occur due to the consumption of large non-renewable and renewable sources. The rate of industrialization and economic growth is highly dependent on energy consumption for instance; coal, fossil fuels, gas, oil, and renewable sources. Non-renewable sources are mainly used for transport operations, and industrial and electricity generation. The link between environmental quality, environmental taxes, and energy consumption is important from several points of view for example; sectoral energy consumption, pollutant industries, energy structure policies, price control of products, economic policies, and environmental planning on an international and national level. Energy's demand for final consumption is related to 'final energy demand'. But during the transformation process, it is not described for energy consumption. The energy-consuming sectors in energy statistics are opposite to economics statistics that are used in national standard accounts. (Shahzad, 2020; Ali et al., 2021).

[1] MPhil Scholar, School of Economics, Bahauddin Zakariya University, Multan Pakistan, inshakunwal@gmail.com
[2] Professor, School of Economics, Bahauddin Zakariya University, Multan, Pakistan, ramzansheikh@bzu.edu.pk
[3] Professor, School of Economics, Bahauddin Zakariya University, Multan, Pakistan, zahirfaridi@bzu.edu.pk
[4] PhD Scholar, Department of Statistics, Bahauddin Zakariya University, Multan, Pakistan, imranstat99@gmail.com

With the extension of city size and the increase in urban population, cities are now among the world's foremost donors to greenhouse gas emissions and energy consumption. Energy is a crucial natural resource for society as well as a necessary foundation for economic development. High-speed urbanization automatically increases energy intensity. In developing countries, environmental pollution which is caused by the consumption of primary energy has become a flaming issue of global concern in the process of urbanization. During urbanization, countries should take measures to better energy efficiency and minimize the energy intensity to decrease the consumption of primary energy and control the greenhouse effect (Audi and Ali, 2017; Zhu et al., 2021; Audi et al., 2020).

2. Review of Literature

In this section, we determine the impact of environmental quality on urbanization and energy consumption Table 1 presents the summary of studies on the quality of the environment, energy consumption and urbanization.

The first section is based on environmental quality or urbanization. Previous studies used CO2 emission and carbon footprint proxy for environmental quality. In most reviews, the urban population density and percentage of the total urban population were measured as a proxy of urbanization. The findings of these papers pointed out the mixed results in different countries. Positively link between environmental quality and urbanization was due to the urban population or migration of people from rural to urban areas for a better lifestyle, people use private transport rather than public transport, and also due to the threshold effect in these reviews. Some studies indicated the negative relationship between environmental quality and urbanization. Urbanization negatively influenced environmental quality by increasing pressure on natural resources in these studies.

In the next section, the researchers explained the relationship between environmental quality and energy consumption. Most of the studies measured electricity consumption and energy use as a proxy for energy consumption. The proxy used for quality of environment were greenhouse gases, CO2 and ecological footprint in these studies. There were mixed results estimated in developing and developed countries by analyzing these reviews. Most of the studies explored the positive association between environmental quality and energy consumption because of fossil fuel burning, extra usage of NREN resources, and also due to urbanization. But some studies indicated a negative relationship between environmental quality and energy consumption due to increasing consumption of renewable energy resources. The studies showed that CO2 emissions can reduce by using solar, wind or nuclear power plants.

The last section was related to energy intensity and consumption with urbanization. Energy consumption was measured by proxy variables that are: per capita total use power (oil's kilogram equivalent), total coal, and electrical energy. But above-mentioned reviews measured the energy intensity and residential and automobile energy use proxy for energy consumption. Urbanization impact was measured by urban population density and non-agricultural population. The empirical findings of these papers explored the mixed results in developing and developed countries. Most of the studies showed a positive association between energy consumption, energy intensity, and urbanization in developing countries. The positive linkage between these variables was due to more energy-intensive production or busier traffic as well as overcrowding of urban areas. Some studies pointed out the negative relationship between energy consumption, energy intensity, and urbanization due to public transportation systems and also the use of technological mechanisms i.e., efficient home appliances, energy-saving buildings, and fuel-efficient transportation in developed countries.

The earlier studies explained energy consumption and urbanization's impact on environmental quality in limited Asian countries. No previous study was able to explain this relationship among variables as a whole Asian country. But our study tries to find out variables that impact CO2 emission in 32 Asian countries. In this study, we have taken the data from Energy Information Administration (EIA) and World Development Indicators (WDI). There are different techniques used in previous studies like FMOLS, DOLS, impulse response function or generalized method of moments (GMM) etc. Panel ARDL method is applied in the present study. We have also used causality analysis to check the uni-variate and bi-variate directions among variables.

3. Model Specification

To explain the connection among carbon dioxide, urbanization or energy consumption of 32 Asian countries is the main objective of this paper.

The functional form of the model is:

$$CO2 = f(POPD, GDPG, GDPG^2, REN, NREN, URBAN, TRADE) \quad \textbf{(1)}$$

The econometric form of the model is:

$$CO2_{it} = \lambda_0 + \lambda_1 POPD_{it} + \lambda_2 GDPG_{it} + \lambda_3 GDPG_{it}^2 + \lambda_4 REN_{it} + \lambda_5 NREN_{it} + \lambda_6 URBAN_{it} + \lambda_7 TRADE_{it} + \varepsilon_{it} \quad \textbf{(2)}$$

Where subscript i refers to countries, t indicates the time period for different years and λ denotes the slope of variables. CO_2 shows the carbon dioxide emission, POPD is the population density, GDPG depicts the GDP per capita growth rate, $GDPG^2$ is the square of per capita growth, REN shows the renewable energy, NREN indicates non-renewable energy consumption, URBAN presents the urban population, TR is trade ε is the error term. Proxy used for environmental quality is carbon emission which is measured by metric tons per capita and urban population is measured as a percentage of the total population used as a proxy for urbanization and trade openness is measured in the term of the trade (exports, imports) as a share of GDP. Population density is the number of individuals per square kilometre of land area. In this model, CO_2 emission is used as a dependent variable whereas per capita GDP growth, the square of GDP per capita growth, urban population, renewable and non-renewable energy, population density and trade are used as explanatory variables.

Table 1: Summary of Review of Literature

Reference(s)	Time Period	Country	Dependent Variable	Independent Variables	Methodology	Main Results
			Summary of the Studies on Environmental Quality and Urbanization			
Hanif (2018)	1995 to 2015	Sub-Saharan Africa	CO_2 emissions	Per capita economic growth (GDP, GDP^2), Renewable and nonrenewable (solid and fossil fuel) energy consumption, Urbanization	System generalized method of moments (SGMM)	Per capita GDP (+), Per capita GDP^2(-). Fossil and solid fuels are significant. Renewable energy consumption (-), Urbanization (+)
Pata et al (2018)	1974 to 2014	Turkey	CO_2 emissions	Per capita income (GDP, GDP^2), Per capita renewable energy consumption (Hydropower, alternative, total renewable energy consumption), Urbanization, and financial development.	Autoregressive distributed lag (ARDL), Fully modified ordinary least square (FMOLS), Canonical cointegration regression.	Urbanization (+), Renewable energy consumption (-), GDP (+), GDP^2 (-), Financial development (+).
Nathanial et al (2019)	1965 to 2014	South Africa	Ecological footprint	Urbanization, Energy use, financial development, Per capita GDP	Autoregressive distributed lag (ARDL), Fully modified ordinary least square (FMOLS) Dynamic ordinary least square (DOLS), Canonical cointegration regression (CCR)	Urbanization (+), Energy use (-), Financial development (+), Per capita GDP (+)
Abbasi et al (2020)	1982 to 2017	8 Asian countries	CO_2 emissions	Urbanization, Energy consumption, GDP, Financial development, trade openness	Stochastic impacts by regression on population, affluence, and technology (STIRPAT), Ordinary least square (OLS), Vector error correction model	Urbanization (+), Energy consumption (+), GDP (+), Financial development (-), Trade openness (-)
Godli et al (2021)	1980 to 2018	Pakistan	Ecological footprint	Transportation services, financial development, GDP, GDP^2, Urbanization	Autoregressive distributed lag (QARDL), Wald test	Transportation services (-), Financial development (-), Urbanization (+), GDP (+), GDP^2 (-)
			Summary of the Studies on Environmental Quality and Energy Consumption			
Rafindadi et al (2017)	1990 to 2014	Gulf Cooperation Council countries	CO_2 emission	Foreign direct investment, direct investment, Per capita GDP and GDP^2, Energy consumption, Energy use, Relative per capita income	Mean group, Pooled mean group, and Dynamic fixed effect (Autoregressive distributed lag estimation)	Per capita GDP (-), Per capita GDP^2 (-), Foreign direct investment (-), Direct investment (-), Energy consumption (+), Energy intensity (+) (-), Relative per capita income (-).
Phrakhroupatnontakitti et al (2019)	1971 to 2005	4 Asian countries	CO_2 emissions	Energy consumption, GDP, GDP^2	Error correction model	Energy consumption (+), GDP (+), Square of GDP (-)

Liu et al (2019)	1980 to 2016	Pakistan	CO_2 emissions	Energy consumption, Tourism receipts, GDP per capita	Autoregressive distributed lag (ARDL), Granger causality, Dynamic ordinary least square (DOLS)	GDP per capita (+), Tourism receipts (+), Energy consumption (+)
Khan et al (2020)	1971 to 2016	USA	CO_2 emissions and ecological footprint (EFP)	Natural resources, Renewable and nonrenewable energy consumption, Population, Biocapacity	System generalized method of moments (SGMM), Generalized linear model (GLM), and Robust least square model.	Nonrenewable energy consumption (+) Population (+), Biocapacity (+). Natural resources (-), Renewable energy consumption (-) in both models.
Rehman and Vu (2021)	1971 to 2018	China	Per capita CO_2 emissions	Energy consumption per capita, GDP, GDP^2, Population density, Exports	Autoregressive distributed lag (ARDL), Vector error correction model (VECM), Granger causality	Energy consumption per capita (+), GDP (+), GDP^2 (-), Population density (-), Exports (-)
		Summary of the Studies on Energy Consumption/ Energy Intensity and Urbanization				
Wang et al (2019)	1980 to 2015	186 countries	Per capita energy consumption	Economic growth (GDP) Urbanization, Energy prices.	Granger causality approach, Impulse response function (IRF) Ordinary least square method (OLS)	OLS result: Urbanization (-) (+), Energy prices (+), GDP (-) IRS results: Urbanization (+), GDP (+), Energy prices (+) (-)
Du and Lin (2019)	2003 to 2015	279 cities in China	Automobile energy consumption, Energy use per capita	Population, Per capita income, Urbanization, Proportion of tertiary industry	Stochastic impacts by regression on population, affluence, and technology (STIRPAT), Generalized method of moments (GMM), Threshold model	Population (+), Per capita income (+), Urbanization (+), Proportion of tertiary industry (significant)
Wang et al (2020)	1990 to 2015	136 developing and developed countries	Residential energy consumption	Population, Urbanization, Affluence	Stochastic impacts by regression on population, affluence, and technology (STIRPAT), Fully modified ordinary least square (FMOLS)	Population (-), Affluence (+), Urbanization (-)
Aboagye and Amponsah (2020)	1980 to 2015	36 Sub-Saharan African countries	Energy intensity	Urbanization, Economic growth (GDP, GDP^2), Industrialization, Foreign direct investment, Trade, Inflation rate	Generalized method of moments (GMM)	Urbanization (+), GDP (+), GDP2 (-), Industrialization (+), Foreign direct investment (-), Trade openness (-), Inflation rate (+)
Zhu et al (2021)	1990 to 2015	38 OECD countries	Energy intensity	Urbanization, CO_2 emissions, economic growth, Industrialization level, Openness	Generalized method of moments (GMM), Ordinary least square (OLS)	Urbanization (+) (-), CO_2 emissions (+), Industrialization (-), Openness (-)

4. Data: Description, Definition, and Sources

In this section, we explain the data description of all variables that are presented in Table 4. This study covers the panel data over the period 1980 to 2020. Data for affluence or its square, urban population, and trade were collected for a set of 32 Asian countries. Renewable and non-renewable energy consumption data were acquired from the Energy Information Administration (EIA) whereas data for all other variables were obtained from the World Development Indicators (WDI).

Table 2: Variables: Description and Sources

Variable	Description	Source
	Dependent Variable	
CO_2	CO_2 emissions (metric tons per capita)	WDI
	Explanatory Variables	
REN	Renewable Energy Consumption (quad Btu)	Energy Information
NREN	Non-Renewable Energy Consumption (quad Btu)	Administration (EIA)
POPD	Population density (people per sq. km of land area)	
GDPG	GDP per capita growth (annual %)	
$GDPG^2$	Square of GDP per capita growth (annual %)	WDI
URBAN	Urban population (% of the total population)	
TRADE	Trade (% of GDP)	

4.1. CO_2 emission

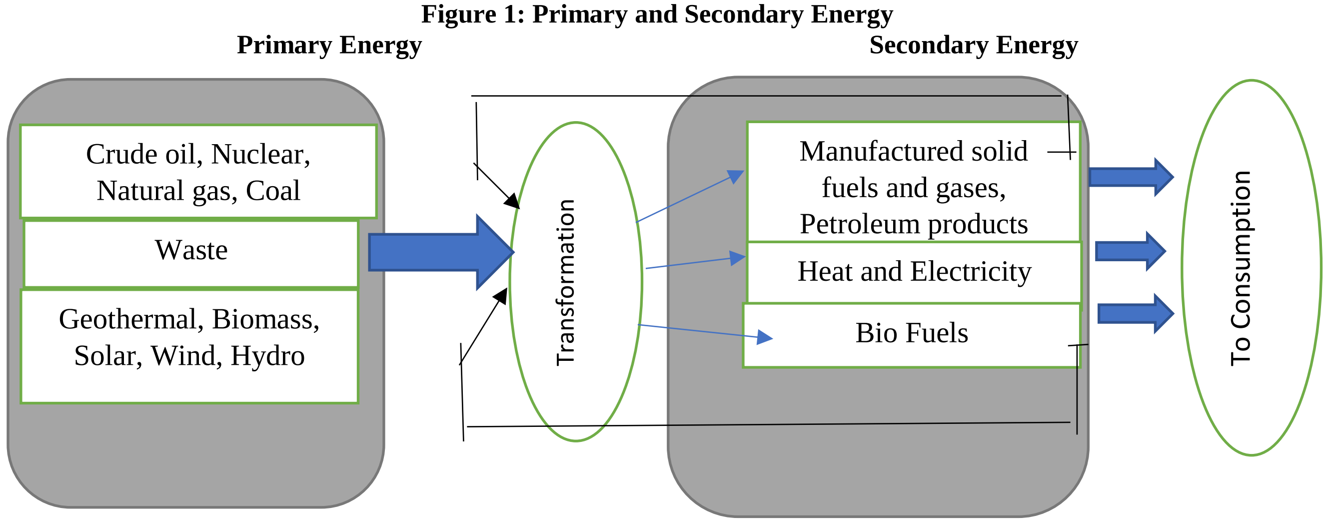
It is one of the major greenhouse gas emissions which generating by human economic activities and influences human development by leading to climate change. CO_2 emissions consist of a very small part of the Earth's atmosphere but this is the main source of greenhouse gas emissions leading to environmental degradation. However, overmuch carbon dioxide arises at the level of the atmosphere which might prove to be harmful. Carbon dioxide is the least effective per molecule rather than nitrous oxide. CO_2 can be from both natural and human sources including, the burning of fossil fuels, biomass, the urbanization process, and also cement production. It can be reduced either by using alternative sources of energy or by the use of less energy than creating less or no carbon dioxide. Plants and animals would not be able to live without this odourless and colourless gas. CO_2 emissions are measured in metric tons per capita (Theodore and Theodore, 2021).

$$Carbon\,Dioxide\,Emission = \frac{CO_2\,Emission}{Population} \times 100 \quad \textbf{(3)}$$

4.2. Primary and Secondary Energy

Primary energy can be used directly. It has not under furnished for any transformation process. Secondary energy is found from a primary source of energy and this type of energy has employing a shift and rebirth process. Gas, coal, and oil are converted into electricity and steam. Electricity and oil products are secondary energies (Bhattacharyya, 2019).

Figure 1: Primary and Secondary Energy



Source: Authors'own elaboration

4.3. Renewable energy

It is gathered from unlimited natural resources and these resources can be filled again in a short time period. It is measured in quadrillion British Thermal Units. The main renewable energies are geothermal, waves, wind energy, solar energy, hydropower, biomass, and tides. Solar energy is the best renewable energy source that transitions sunlight into electricity instantly by using photovoltaics. Wind energy is derived by using wind turbines to produce electricity. The other renewable source is geothermal energy which is generated naturally by Earth itself and also from the decay of radioactive particles. Hydropower is power obtained from the energy from fast running water or flowing water and this water can be captured and then twisted into electricity. Biomass is a particular term for energy in which energy is produced from materials like animal wastes, straws, and wood (Nelson, 2011; Ali et al., 2022).

4.4. Non-renewable Energy

It is a limited natural resource that cannot exchange in a short time period. It is measured in quadrillion British Thermal Units. Fossil fuels may be generated by the decomposition of animal and plant matter. Fossil fuels are known as the primary source of energy. Coal is a solid, black-coloured, and hard form of fossil fuel. It is the manufacture of nitrogen, carbon, hydrogen, and sulfur. The formation process of coal is known as coalification. It is used in industries as fuel and producing electricity. Natural gas is a mixture of hydrocarbons and other gaseous substances like hydrogen sulfide, carbon dioxide, helium, and nitrogen. It is also pulled out through the boring process. It is an odourless, colourless, and non-toxic fossil fuel. Three types of wells come from raw natural gas such as condensate wells, oil wells, and gas wells. Crude oil is a mixture of hydrocarbons and solid sedimentary rocks. It exists in a liquid phase which is a pill out through a drilling process (Devold, 2013; Audi and Ali, 2023).

4.5. Population density (People per sq. km of the land area)

It is defined as the number of individuals per square kilometre of land area. Due to the overutilization of non-renewable energy like natural gas, coal, and oil, high population density can cause the degradation of the environment and exhaustion of natural resources such as energy, arable land, water, and forest (Elliot et al, 2014). It can be calculated as:

$$Population\,Density = \frac{Mid\ year\ population}{Land\ area\left(SqKm\right)} \times 100 \quad \textbf{(4)}$$

4.6. GDP per capita growth (annual %)

The annual growth rate of per capita gross domestic product is measured as a percentage change in per capita real gross domestic product between two sequentially years. This measurement of the gross domestic product talks about the growth of the economy and the average living standard of people (Yang et al, 2015). The growth rate of gross domestic product can be calculated as:

$$GDP\ per\ capita\ growth = \frac{GDP\ at\ current\ price}{Population} \times 100 \quad \textbf{(5)}$$

4.7. Square of per capita GDP growth (annual %)

It is calculated by obtaining the square of GDP growth per capita.

$$Square\,of\ \ per\ capita\,GDP\ growth = \left(\frac{GDPat\ current\ price}{Population} \times 100\right)^2$$

4.8. Urban Population (percentage of aggregate population)

The number of individuals that are living in the sector of urban known as the urban population. According to the Census Bureau, the urban population of nations is defined as all individuals living in urban clusters and urbanized areas. The annual growth rate of the urban population can speculate the situation of the population moving to cities, urban economic growth, and urban extension. Due to the expectation of better living standards, the movement of the population arises from rural to urban areas. It can be measured as:

$$PU = \frac{U}{P} \times 100 \quad \textbf{(6)}$$

Where PU denotes the ratio of urban sector's residents, U indicates the total urban population and P shows the total population (Sullivan, 1996; Audi and Ali, 2023).

4.8. Trade (% of GDP)

Trade or trade openness acts as a standard of relative international trade's significance to a nation's economy. From trade, the economy of the country can be promoted because it helps to use the resources properly and exploit the economies of scale. Trade is measured as a proportion of the total trade of a country to the gross domestic product of a country in a year. (Aboagye and Amponsah, 2020; Ashiq et al., 2023)

$$Trade = \frac{Exports + \mathrm{Im}\,ports}{Gross\,domestic\ product} \times 100 \quad \textbf{(7)}$$

5. Methodology: Panel ARDL

The Unrestricted Error Correction Models (UECMs) connecting with the urbanization, energy consumption, and CO_2 emission of Asian countries are given below separately:

$$\Delta CO2_{it} = \partial + \gamma_1 (CO2)_{it-1} + \gamma_2 (POPD)_{it-1} + \gamma_3 (GDPG)_{it-1} + \gamma_4 (GDPG^2)_{it-1} + \gamma_5 (REN)_{it-1}$$
$$+\gamma_6 (NREN)_{it-1} + \gamma_7 (URBAN)_{it-1} + \gamma_8 (TRADE)_{it-1} + \sum_{i=1}^{\chi_1} \psi_{1i} \Delta (CO2)_{it-i} + \sum_{i=0}^{\chi_2} \psi_{2i} \Delta (POPD)_{it-i}$$
$$+\sum_{i=0}^{\chi_3} \psi_{3i} \Delta (GDPG)_{it-i} + \sum_{i=0}^{\chi_4} \psi_{4i} \Delta (GDPG^2)_{it-i} + \sum_{i=0}^{\chi_5} \psi_{5i} \Delta (REN)_{it-i} + \sum_{i=0}^{\chi_6} \psi_{6i} \Delta (NREN)_{it-i}$$
$$+\sum_{i=0}^{\chi_7} \psi_{7i} \Delta (URBAN)_{it-i} + \sum_{i=0}^{\chi_8} \psi_{8i} \Delta (TRADE)_{it-i} + \varepsilon_{it} \quad \textbf{(8)}$$

The parameters γ_{it} are the comparable long-run multipliers where the ψ_{it} (for, i=0) are the short-run dynamic factors and others ψ_{it} (for i=1,2…. $\chi_1, \chi_2, ...\chi_8$) are VAR coefficients of the ARDL models. The first difference operator is Δ and μ_{it} is the white noise error term.

If there is an existence of a long-run relationship then the long-run factors can be calculated by using the following equation for Asian countries:

$$CO2_{it} = \partial + \sum_{i=1}^{\chi_1} \rho_{1i} (CO2)_{it-i} + \sum_{i=0}^{\chi_2} \rho_{2i} (POPD)_{it-i} + \sum_{i=0}^{\chi_3} \rho_{3i} (GDPG)_{it-i} + \sum_{i=0}^{\chi_4} \rho_{4i} (GDPG^2)_{it-i}$$
$$+\sum_{i=0}^{\chi_5} \rho_{5i} (REN)_{it-i} + \sum_{i=0}^{\chi_6} \rho_{6i} (NREN)_{it-i} + \sum_{i=0}^{\chi_7} \rho_{7i} (URBAN)_{it-i} + \sum_{i=0}^{\chi_8} \rho_{8i} (TRADE)_{it-i} + \varepsilon_{it} \quad \textbf{(9)}$$

In equation (9), the long-run parameters are denoted by the factors that are connected with summation signs.

The short-run dynamics can be created by approximating the following equation for Asian countries:

$$\Delta CO2_{it} = \partial + \sum_{i=1}^{\chi_1} \delta_{1i} \Delta (CO2)_{it-i} + \sum_{i=0}^{\chi_2} \delta_{2i} \Delta (POPD)_{it-i} + \sum_{i=0}^{\chi_3} \delta_{3i} \Delta (GDPG)_{it-i} + \sum_{i=0}^{\chi_4} \delta_{4i} \Delta (GDPG^2)_{it-i}$$
$$+\sum_{i=0}^{\chi_5} \delta_{5i} \Delta (REN)_{it-i} + \sum_{i=0}^{\chi_6} \delta_{6i} \Delta (NREN)_{it-i} + \sum_{i=0}^{\chi_7} \delta_{7i} \Delta (URBAN)_{it-i} + \sum_{i=0}^{\chi_8} \delta_{8i} \Delta (TRADE)_{it-i} + \varpi ECM_{it-1} + \varepsilon_{it} \quad \textbf{(10)}$$

In equation (10), the short-run parameters are indicated by the factors that are linked with summation signs. The coefficient of ECM stands for (ϖ) in both equations, demonstrating the speed of adjustment towards the long-run equilibrium, and the adjustment's coefficient should be statistically significant and negative for the intersection.

The Granger causality shows the direction of causality among variables either uni-variate, bi-variate or no causality.

$$CO2_{it} = \sum_{i=1}^{n} \kappa_i REN_{it-i} + \sum_{j=1}^{n} \iota_j CO2_{it-j} + \mu_{1it} \quad \textbf{(11)}$$
$$REN_{it} = \sum_{i=1}^{n} \lambda_i REN_{it-i} + \sum_{j=1}^{n} \delta_j CO2_{it-j} + \mu_{2it}$$

Equation (11) indicates that bi-variate causality exists between renewable energy and carbon emission.

$$CO2_{it} = \sum_{i=1}^{n} o_i NREN_{it-i} + \sum_{j=1}^{n} \rho_j CO2_{it-j} + \mu_{1it} \quad \textbf{(12)}$$
$$NREN_{it} = \sum_{i=1}^{n} \lambda_i NREN_{it-i} + \sum_{j=1}^{n} \delta_j CO2_{it-j} + \mu_{2it}$$

In equation (12), there is uni-variate causality that occurs between non-renewable energy and CO_2 emission.

$$CO2_{it} = \sum_{i=1}^{n} \mathrm{M}_i URBAN_{it-i} + \sum_{j=1}^{n} \mathrm{N}_j CO2_{it-j} + \mu_{1it} \quad \textbf{(13)}$$
$$URBAN_{it} = \sum_{i=1}^{n} \lambda_i URBAN_{it-i} + \sum_{j=1}^{n} \delta_j CO2_{it-j} + \mu_{2it}$$

Equation (13) denotes that there is no causality exists between urban population and carbon dioxide emission.

6. Results and Discussions

In this section, we are describing the results and discussions of this paper.

6.1. Unit Root Analysis

The unit root is used to check the stationarity of variables or whether the series is stable or not. Stationary means the order of integration is zero. In other words, the variable is directly stationary which is denoted by I (0). If the variable is non-stationary, then how many differences need to make it stationary. By taking one difference, the variable becomes stationary, it is denoted by I (1) or integrated of order one. I (1) mean that the series itself is not stationary but after taking the one difference, this series becomes stationary. Similarly, I (2) mean the series becomes stationary after taking the two differences.

Table 5 provides the detail about the panel unit root tests. Four tests are used for panel unit root analysis.

(1) Levin-Lin-Chu test
(2) Im-Pesaran-Shin test
(3) Augmented Dickey-Fuller (ADF) Fisher Chi-Square test
(4) Phillips-Perron test

The probability value of CO_2 emission, renewable and non-renewable energy, population density and trade are greater than 0.05, so we accept H_0 which means that series are non-stationary or integrated of order one I (1). The probability value of the series of urban population and GDPG are less than 0.05 which shows that the series is stationary or the order of integration is zero I (0) because we reject H_o.

6.2. Long-run and Error Correction Analysis

This section covers the long-run as well as short-run analysis of all variables. Table 6 explains the panel ARDL estimates of variables. In this table, CO_2 emission is the dependent variable whereas population density (POPD), GDPG, square of GDPG, renewable energy (REN), non-renewable energy (NREN), urbanization (URB), and trade (TR) are independent variables.

Population density is the first independent variable. Its value represents the positive and significant effect on carbon emission. This suggests that increasing population aggravates the environmental quality as the growing population exerts pressure on the environment through poor waste disposal and limited resources through high demand for public and private facilities. Several environmental impacts are caused by the high population density. Due to the overuse of non-renewable energy such as natural gas, coal, and oil, high population density can cause the consumption of natural resources (energy, cultivable land, forest, water, etc.) and degradation of the environment. Our results are in line with expectations. The other studies by Zhang and Lin (2012), Sadorsky (2013), Shafiei and Salim (2013), Rafiq and Nielsen (2016), Salim et al. (2017), Adams et al. (2020) and Khan et al. (2021) found a positive impact of population density with CO_2 emission.[5]

GDPG is the second explanatory variable. The estimated long-run coefficient value of the GDP per capita growth is 0.08. This value shows a positive plus significant effect on CO_2. This shows that due to economic development in the absence of energy conservation policies, developing countries consume more energy as a result environment will be more contaminated. More specifically, the bulk of the countries are mostly agrarian economies, the findings also indicate that these countries increase their agricultural production keeping in view expanding the output which increases the extent of environmental destruction. The prior studies by Kasman and Duman (2014), Farhani and Ozturk (2015), Rafiq and Neilsen (2016), Hanif (2018), Pata et al. (2018), Ali et al. (2019), Nathenial et al. (2019), Liu et al. (2019), Abbasi (2020), and Godli et al. (2021) found the positive link with carbon dioxide.[6]

Per capita GDP square growth is the third independent variable. Its coefficient value represents the negative and significant effect with dependent variable. Economic growth is one of the keys perpetrated in dropping the environmental quality. In Asian countries, CO_2 emission is initially high as affluence enhances and sinks after a certain level of economic growth has been achieved. The earlier studies by Halicioglu (2009), Hagger (2011), Kasman and Duman (2014), Rafiq and Neilsen (2016), Salim et al. (2017), Pata et al. (2018), and Godli et al. (2021) found a negative association between these variables. In these studies, findings supported the environmental Kuznets curve (EKC) hypothesis which shows the inverted U-shaped relationship between economic growth and CO_2 emission. According to this, environmental degradation initially enhances income until it reaches its saturation point, then declines.[7]

The fourth variable is renewable energy consumption. Its negatively or significantly affect the dependent variable. This indicates that CO_2 emission will lead to a decrease if even a small number of renewable sources are used. Moreover, CO_2 emission will be decreased by increasing consumption of renewable energy and foreign direct investment by supporting the pollution haloes hypothesis. The previous studies by Shafiei and Salim (2013), Rafiq and Nielsen (2016), Salim (2017), Hanif (2018), Pata et al. (2018), and Khan et al (2021) found the negative effect of renewable energy consumption on CO_2 emission.

[5] However, the following studies have found the negative relationship between population density and CO_2 emission. For example, Rehman and Vu (2021) showed the negative effect between POPD and CO_2.

[6] However, the following studies explained the negative and non-linear association between GDPG and CO_2 emission. For example, Lean and Smyth, 2010; Hagger, 2011; Shehbaz et al, 2012; Dogan and Turkekul, 2015; Mert and Boluk, 2016 and Rafindadi et al, 2017.

[7] Even so, the following studies showed the positive relationship between square of GDPG and CO_2 emission. For example, Shafiei and Salim, 2013; Farhani and Ozturk, 2015; Dogan and Turkekul, 2015; Mert and Boluk, 2016. EKC hypothesis was not valid in these studies.

Table 3: Results of Panel Unit Root Tests

Variable	Intercept				Intercept and Trend				None			Result
	LLC Test	IPS Test	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	LLC Test	IPS Test	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	LLC Test	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	
CO2	5.19773 (1.0000)	7.45594 (1.0000)	26.2023 (0.9998)	32.9029 (0.9941)	0.91670 (0.8204)	2.98207 (0.9986)	42.7193 (0.9043)	48.1511 (0.7629)	9.26220 (1.0000)	19.5629 (1.0000)	17.9627 (1.0000)	I (1)
POPD	14.3135 (1.0000)	9.19378 (1.0000)	300.325 (0.0000)	183.485 (0.0000)	2.80390 (0.9975)	10.8444 (1.0000)	42.8914 (1.0000)	28.2145 (1.0000)	62.5817 (1.0000)	0.00193 (1.0000)	0.19337 (1.0000)	I (1)
GDPG	-15.8215 (0.0000)	-18.6614 (0.0000)	424.411 (0.0000)	434.867 (0.0000)	-15.1747 (0.0000)	-17.6337 (0.0000)	449.771 (0.0000)	802.492 (0.0000)	-12.8581 (0.0000)	471.596 (0.0000)	469.667 (0.0000)	I (0)
REN	0.89749 (0.8153)	1.79996 (0.9641)	57.8490 (0.5547)	50.5139 (0.8036)	-2.44518 (0.0072)	-2.29761 (0.0108)	84.8397 (0.0191)	96.9981 (0.0018)	4.70972 (1.0000)	42.2838 (0.9598)	22.1576 (1.0000)	I (1)
NREN	0.28821 (0.6134)	3.37563 (0.9996)	38.3007 (0.9869)	30.9655 (0.9993)	-2.16708 (0.0151)	-0.68956 (0.2452)	58.9761 (0.5132)	65.4833 (0.2924)	4.87184 (1.0000)	21.5860 (1.0000)	15.0787 (1.0000)	I (1)
URBAN	-0.58232 (0.2802)	3.70149 (0.9999)	60.6526 (0.4522)	131.429 (0.0000)	-6.91687 (0.0000)	-1.30381 (0.0961)	117.245 (0.0000)	66.4096 (0.2657)	2.49317 (0.9937)	19.3180 (1.0000)	2.61548 (1.0000)	I(0)
TRADE	-1.99790 (0.0229)	-2.0540 (0.0200)	91.9830 (0.0080)	93.1858 (0.0064)	1.04032 (0.8509)	1.05250 (0.8537)	69.3912 (0.2425)	69.0196 (0.2523)	-0.36793 (0.3565)	45.5022 (0.9426))	44.5434 (0.9539)	I (1)

Table 4: Long-Run Panel ARDL Estimates of Urbanization, Energy Consumption and CO2 Emission Model

Dependent Variable: D(CO2)

Selected Model: ARDL (1, 1, 1, 1,1, 1, 1, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
POPD	0.1184	0.0030	39.9427	0.0000
GDPG	0.0857	0.0223	3.8407	0.0001
$GDPG^2$	-0.0736	0.0216	-3.4007	0.0007
REN	-0.0447	0.0103	-4.3512	0.0000
NREN	0.0694	0.0433	1.6043	0.1090
URBAN	0.0185	0.0047	3.9336	0.0001
TRADE	0.0116	0.0022	5.1396	0.0000
C	0.3191	0.2136	1.4943	0.1354

Non-renewable energy is the fifth variable. The coefficient value of this variable is 0.0694. This value shows the insignificant or positive effect on CO_2 emission. This suggests that due to fossil fuel combustion and fast economic growth, pollution emissions are increasing in Asian countries. In many Asian countries, indoor air pollution from cooking, heating, lighting, and cooling is a cause of tuberculosis, lung cancer, blindness, and heart disease whereas respiratory diseases are caused by motor vehicle emissions from outdoor pollution. Similarly, in many industries, the use of more machinery is needed for production activities and requires more energy which put pressure on the environment leading to more CO_2 emissions in the atmosphere. The former studies by Salim (2013), Nielsen and Rafiq (2016), Salim et al. (2017), Hanif (2018), Mohiuddin et al. (2016), and Khan et al. (2020) found a positive association between non-renewable energy resources and CO_2 emission.

The second last variable is the urban population. The coefficient value of the urban population is 0.0185 and this value has significant and positive effect on CO_2. The findings reveal that urbanization not only includes the migration of the labor force from the traditional sector in rural areas to the modern and service sector in urban areas but also the transfer of products from in-house production to commercial goods as well as the acceleration of the development of private and public transport which requires additional energy leading to more CO_2 emission. Similarly, the theory of ecological modernization and urban environmental transition accepted that higher urbanization is connected with higher economic activity and this gives the higher wealth and wealthier residents which often demands more energy-intensive products, for example, air conditioning, automobiles, etc., leading to more carbon dioxide emission. In Asian countries, people prefer to migrate from rural to urban areas to attain better urban facilities and services, this puts pressure on infrastructure which commonly leads to deforestation. In developing countries, greater deforestation enhances the several folds of carbon dioxide emission. Our results are in line with previous findings. The other studies by Dogan and Turkekul (2015), Sehrawat et al. (2015), Salim et al. (2017), Hanif (2018), Pata et al. (2018), Ali et al. (2019), Abbasi (2020), and Godli et al. (2021) found the positive effect on CO_2 emission.[8]

The last variable is trade openness. The estimated long-run coefficient value of the trade is 0.0116 which depicts positive and significant effect with dependent variable . This suggests that an increase in the volume of trade led to enhance pollution. For most developing countries, the sign of this variable is positive because these countries tend to produce several goods without having tools for environmental protection. As a result, dirty industries emit a heavy share of pollutants. Due to dirty production, a higher level of trade openness will enhance pollution under the weaker environmental rules of developing countries. The prior studies by Hossain (2011), Shafiei and Salim (2013), Kasman and Duman (2014), Farhani and Ozturk (2015), and Sherawat et al. (2015) found the positive impact of trade openness on CO_2 emission.[9]

Error Correction Analysis

This section explains the short-run analysis or error correction estimation of variables. In the short run, the sign of the error correction term is negative and significant;meaning that error occurs in the short-run will remove in the long-run and the speed of adjustment means how much time it takes to remove this disequilibrium. So, the adjustment's speed is -0.07.

---

[8] However, the following studies presented the negative relationship between urbanization and CO_2 emission. For example, Sharma, 2010; Sadorsky, 2013; Bahera and Dash, 2016; Salim et al, 2017 and Adams et al, 2020. These studies indicated that for the public infrastructure, economies of the scale are facilitated by the helps of increasing urbanization leading to lower environmental damages.

[9] Yet, the following reviews conducted the negative relationship between trade and CO_2 emission. Fr example, Dogan and Turkekul, 2015; Rafiq and Nielsen, 2016; Salim et al. 2017; Abbasi, 2020 and Rehman and Vu, 2021.

Table 5: Error Correction Estimates of Urbanization, Energy Consumption, and CO2 Emission Model

Dependent Variable: D (CO2)				
Selected Model: ARDL (1, 1, 1, 1,1, 1, 1, 1)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
COINTEQ01	-0.0740	0.0179	-4.1262	0.0000
D(POPD)	-0.0192	0.0017	-11.5088	0.0000
D(GDPG)	0.0069	0.0057	1.2091	0.2271
D($GDPG^2$)	-0.0002	0.0011	-0.1605	0.8725
D(REN)	0.4536	0.1732	2.6185	0.0090
D(NREN)	-0.0024	0.0012	-1.9545	0.0511
D(URBAN)	0.7009	0.1179	5.9430	0.0000
D(TRADE)	0.0005	0.0009	0.5810	0.5613
C	-0.0588	0.2387	-0.2465	0.8053

6.3. Causality Analysis

This section elaborates the causality analysis and lag selection criterion. Table 8 represents lag and optimal lag selection criterion which is based on six methods such as log-likelihood, sequentially modified LR test statistic, final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ). According to the LR, the lag is five. Similarly; according to the final prediction error, the Akaike information criterion, Schwarz information criterion, and Hannan-Quinn information criterion lag is also five. So, all methods except the log-likelihood method support lag five. Therefore, the optimal lag is five.

Table 6: Lag and Optimal Lag Selection Criterion

Endogenous variables: CO2 REN NREN URBAN						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-7729.662	NA	445290.2	24.35799	24.38604	24.36888
1	-285.2621	14771.56	3.07e-05	0.961455	1.101727	1.015921
2	756.3120	2053.623	1.22e-06	-2.268699	-2.016210	-2.170661
3	873.7100	229.9892	8.83e-07	-2.588063	-2.223357	-2.446452
4	893.0043	37.55544	8.74e-07	-2.598439	-2.121515	-2.413256
5	984.0250	176.0212*	6.90e-07*	-2.834724*	-2.245584*	-2.605969*

The Granger causality analysis shows the direction of causality either is uni-variate, bi-variate, or no causality among variables. The direction of variables find out on the basis of the probability value. Table 9 estimates the Granger causality analysis of variables. According to this table, CO_2 and renewable energy both cause each other. It refers to the bi-variate causality between these variables.

Table 9: Granger Causality Analysis

Null Hypothesis	Obs	F-Statistics	Prob.
REN↛CO2	756	3.10554	0.0454
CO2 ↛ REN		3.68929	0.0254
NREN ↛ CO2	719	7.00806	0.0010
CO2 ↛ NREN		0.55156	0.0763
URBAN↛ CO2	756	9.74603	7.E-05
CO2 ↛ URBAN		0.35765	0.6994
NREN ↛ REN	1178	60.6844	0.0000
REN ↛ NREN		35.9113	0.0001
URBAN ↛ REN	1248	1.95132	0.0425
REN ↛ URBAN		1.26508	0.0826
URBAN↛ NREN	1178	1.37511	0.2532
NREN ↛ URBAN		4.32759	0.0134

Non-renewable energy consumption cause CO_2 emission but CO_2 does not cause non-renewable energy. It means, there is uni-variate causality exists between non-renewable energy consumption and CO_2 emission. The urban population does not cause CO_2 emission and CO_2 emission does not cause urban population. So,there is no causality exists between urban population and CO_2 emission. Non-renewable energy consumption cause renewable energy and renewable energy cause non-renewable energy. It suggests that there is bi-variate causality occurs between non-renewable and renewable energy consumption. Urban population cause renewable energy and but renewable energy does not cause urban population. Thus, there is one-way causality exists among urban population and renewable energy consumption. Urban population and non-renewable energy cause each other. It means that there is bi-variate causality between urban population and non-renewable energy consumption.

7. Conclusions and Policy Implications

This paper explains the nexus between urbanization, energy consumption and CO_2 emission of 32 Asian coutries. In this study, CO_2 is the dependent variable that is used as a proxy for environmental quality whereas population density, per capita growth of GDP, renewable energy, $GDPG^2$, non-renewable energy, urban population and openness are used as explanatory variables. The panel data are obtained from Energy Information Administration (EIA) and World Development Indicators (WDI) from 1980 to 2020.

Unit root tests are used to check the stationarity of variables. Our findings reveal that stationary series are found in urban population and GDPG whereas population density, CO_2, renewable and non-renewable energy have non-stationary series. The long-run assessment of our results indicate that non-renewable energy shows an insignificant but positive impact on CO_2 emission because CO_2 increases in Asian countries due to fast economic growth and fossil fuel combustion. Similarly, more energy is required for the use of machinery in the production process in many industries which creates CO_2 emissions in the atmosphere.

Our results also present the positive and significant association between urban population and CO_2 emission according to the theory of ecological modernization and urban environmental transition. Population density and openness have positive and significant; whereas $GDPG^2$ and renewable energy have negative but significant effect on CO_2. In Asian countries, CO_2 emission initially increases with the increase in income but after reaching a saturation point, it decreases due to attainable economic growth. CO_2 emission decrease by using the alternatives of renewable energy which helps the economies to attain sustainable targets of development. Our findings reveal that error correction's value is also negative. The results of Granger causality represents that bi-variate causality running from renewable energy to CO_2 emission, urban population to non-renewable energy, and from non-renewable energy to renewable energy. The results also estimate that there is uni-variate causality running from urban population to renewable energy consumption and from non-renewable energy consumption to CO_2 emission. There is no causality exists between urban population and CO_2 emission.

7.1. Policy Implications

This section covers some policy implications of the present study. It is necessary to suggest some economic policies which may be helpful to reduce CO_2 emission in Asian countries along with urbanization and energy consumption.

- Due to the increased urban population, Asian economies need to obtain sustainable growth. Government planners may boost urbanization with low-carbon transportation systems and urban infrastructure. Policymakers may suggest using the public transportation system rather than the private transportation system to reduce CO_2 emission. In rural areas, Government may supply energy facilities to control the increasing urbanization.
- Renewable energy helps to mitigate pollutants whereas non-renewable energy worsens the environmental quality. The government may encourage the structure of renewable energy producing and supplying infrastructure and support renewable energy development. Energy consumption may be reduced by using other sources like wind energy, biomass, tidal energy, and solar energy. Policymakers may produce a highly emissions-reducing and energy-efficient industry base.
- Due to the absence of energy conservation policies, GDP enhances carbon emission. Therefore, policymakers may adopt more energy conservation policies to mitigate CO_2 emission. In Asian countries, the government may encourage energy efficiency and the growth of clean renewable energy for sustainable growth of the economy.
- Environmental quality is exasperated by increasing population. Policymakers may motivate the population to follow sustainable lifestyles such as the usage of renewable energy, water-saving and energy-saving.
- The increasing volume of trade generates pollution. Government planners may encourage a board-minded trade authority for clean technology transmitted from developed countries.

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.

Aboagye, S., & Nketiah-Amponsah, E. (2016). The implication of economic growth, industrialization, and urbanization on energy intensity in Sub-Saharan Africa. J Appl Econ Bus Res, *6*(4), 297-311.

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

Ali, A., & Audi, M. (2016). The Impact of Income Inequality, Environmental Degradation and Globalization on Life Expectancy in Pakistan: An Empirical Analysis. *International Journal of Economics and Empirical Research*, 4 (4), 182-193.

Ali, A., Audi, M., & Roussel, Y. (2021). Natural Resources Depletion, Renewable Energy Consumption and Environmental Degradation: A Comparative Analysis of Developed and Developing World. *International Journal of Energy Economics and Policy*, *11*(3), 251-260.

Ali, A., Audi, M., Bibi, C., & Roussel, Y. (2021). The Impact of Gender Inequality and Environmental Degradation on Human Well-being in the Case of Pakistan: A Time Series Analysis. *International Journal of Economics and Financial Issues*, *11*(2), 92-99.

Ali, A., Audi, M., Senturk, I., & Roussel, Y. (2022). Do Sectoral Growth Promote CO2 Emissions in Pakistan? Time Series Analysis in Presence of Structural Break. *International Journal of Energy Economics and Policy*, *12*(2), 410-425.

Ali, R., Bakhsh, K., & Yasin, M. A. (2019). Impact of urbanization on CO2 emissions in an emerging economy: evidence from Pakistan. Sustainable Cities and Society, *48*, 101553.

Ashiq, S., Ali, A., & Siddique, H. M. A. (2023). Impact of Innovation on CO2 Emissions in South Asian Countries. *Bulletin of Business and Economics (BBE)*, *12*(2), 201-211.

Audi, M. & Ali, A. (2017). Environmental Degradation, Energy consumption, Population Density and Economic Development in Lebanon: A time series Analysis (1971-2014). *Journal of International Finance and Economics*, 17(1), 7-20.

Audi, M. & Ali, A. (2023). Unveiling the Role of Business Freedom to Determine Environmental Degradation in Developing countries. *International Journal of Energy Economics and Policy*, 13(5), 157-164.

Audi, M., & Ali, A. (2023). The role of environmental conditions and purchasing power parity in determining quality of life among big Asian cities. *International Journal of Energy Economics and Policy*, *13*(3), 292-305.

Audi, M., Ali, A., & Kassem, M. (2020). Greenhouse Gases: A Review of Losses and Benefits. *International Journal of Energy Economics and Policy*, *10*(1), 403.

Barry, C. (2003). FIELD/Martha K. FIELD. Environmental Economics. An Introduction.

Behera, S. R., & Dash, D. P. (2017). The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renewable and Sustainable Energy Reviews, 70, 96-106.

Bhattacharyya, S. C. (2019). Energy economics: concepts, issues, markets, and governance. Springer Nature.

Chikaraishi, M., Fujiwara, A., Kaneko, S., Poumanyvong, P., Komatsu, S., & Kalugin, A. (2015). The moderating effects of urbanization on carbon dioxide emissions: A latent class modeling approach. Technological Forecasting and Social Change, 90, 302-317.

Devold, H. (2013). Oil and gas production handbook: an introduction to oil and gas production, transport, refining, and petrochemical industry. ABB oil and gas.

Dogan, E., & Turkekul, B. (2016). CO 2 emissions, real output, energy consumption, trade, urbanization, and financial development: testing the EKC hypothesis for the USA. Environmental Science and Pollution Research, 23(2), 1203-1213.

Du, Z., & Lin, B. (2019). Changes in automobile energy consumption during urbanization: Evidence from 279 cities in China. Energy Policy, 132, 309-317.

Elliott, R. J., Sun, P., & Zhu, T. (2014). Urbanization and energy intensity: a province-level study for China. Department of Economics, University of Birmingham.

Farhani, S., & Ozturk, I. (2015). Causal relationship between CO 2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environmental Science and Pollution Research, *22*(20), 15663-15676.

Godil, D. I., Ahmad, P., Ashraf, M. S., Sarwat, S., Sharif, A., Shabib-ul-Hasan, S., & Jermsittiparsert, K. (2021). The step towards environmental mitigation in Pakistan: do transportation services, urbanization, and financial development matter? Environmental Science and Pollution Research, 28(17), 21486-21498.

Halicioglu, F. (2009). An econometric study of CO2 emissions, energy consumption, income, and foreign trade in Turkey. Energy Policy, 37(3), 1156-1164.

Hamit-Haggar, M. (2012). Greenhouse gas emissions, energy consumption, and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. Energy Economics, 34(1), 358-364.

Hanif, I. (2018). Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in Sub-Saharan Africa. Environmental Science and Pollution Research, 25(15), 15057-15067.

Hossain, M. S. (2011). Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness, and urbanization of newly industrialized countries. *Energy Policy*, *39*(11), 6991-6999.

Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Economic modeling, 44, 97-103.

Khan, I., Hou, F., & Le, H. P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: Fresh evidence from the United States of America. Science of the Total Environment, 754, 142222.

Lean, H. H., & Smyth, R. (2010). CO2 emissions, electricity consumption, and output in ASEAN. Applied Energy, 87(6), 1858-1864.
Liu, Y., Kumail, T., Ali, W., & Sadiq, F. (2019). The dynamic relationship between CO2 emission, international tourism, and energy consumption in Pakistan: a cointegration approach. Tourism Review.
Lu, W. C. (2017). Greenhouse gas emissions, energy consumption, and economic growth: a panel cointegration analysis for 16 Asian countries. International journal of environmental research and public health, 14(11), 1436.
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.
Mohiuddin, O., Asumadu-Sarkodie, S., & Obaidullah, M. (2016). The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan. Cogent Engineering, 3(1), 1210491.
Nathaniel, S., Nwodo, O., Adediran, A., Sharma, G., Shah, M., & Adeleye, N. (2019). Ecological footprint, urbanization, and energy consumption in South Africa: including the excluded. Environmental Science and Pollution Research, 26(26), 27168-27179.
Nelson, V. C. (2011). Introduction to renewable energy. CRC press.
O'sullivan, A. (1996). Urban economics (Vol. 3). Chicago: Irwin.
Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: testing EKC hypothesis with structural breaks. Journal of Cleaner Production, 187, 770-779.
Phrakhruopatnontakitti, P., Watthanabut, B., & Jermsittiparsert, K. (2020). Energy consumption, economic growth, and environmental degradation in 4 Asian Countries: Malaysia, Myanmar, Vietnam, and Thailand. International Journal of Energy Economics and Policy, 10(2), 529.
Rafindadi, A. A., Muye, I. M., & Kaita, R. A. (2018). The effects of FDI and energy consumption on environmental pollution in predominantly resource-based economies of the GCC. Sustainable Energy Technologies and Assessments, 25, 126-137.
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.
Rahman, M. M., & Vu, X. B. B. (2021). Are Energy Consumption, Population Density, and Exports Causing Environmental Damage in China? Autoregressive Distributed Lag and Vector Error Correction Model Approaches. Sustainability, 13(7), 3749.
Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? Energy Economics, 37, 52-59.
Salim, R. A., Rafiq, S., & Shafiei, S. (2017). Urbanization, energy consumption, and pollutant emission in Asian developing economies: an empirical analysis (No. 718). ADBI Working Paper.
Sehrawat, M., Giri, A. K., & Mohapatra, G. (2015). The impact of financial development, economic growth and energy consumption on environmental degradation: Evidence from India. Management of Environmental Quality: An International Journal.
Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: a comparative analysis. Energy Policy, 66, 547-556.
Shahbaz, M., & Lean, H. H. (2012). Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. Energy Policy, 40, 473-479.
Shahzad, U. (2020). Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications. Environmental Science and Pollution Research, 27(20), 24848-24862.
Sharma, S. S. (2011). Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Applied Energy, 88(1), 376-382.
Theodore, M. K., & Theodore, L. (2021). Introduction to environmental management. CRC Press.
Wang, Q., Lin, J., Zhou, K., Fan, J., & Kwan, M. P. (2020). Does urbanization lead to less residential energy consumption? A comparative study of 136 countries. Energy, 202, 117765.
Wang, Q., Su, M., Li, R., & Ponce, P. (2019). The effects of energy prices, urbanization, and economic growth on energy consumption per capita in 186 countries. Journal of cleaner production, 225, 1017-1032.
Yang, J., Zhang, W., & Zhang, Z. (2015). Impacts of urbanization on renewable energy consumption in China. Journal of Cleaner Production, 114, 443-451.
Zhang, C., & Lin, Y. (2012). Panel estimation for urbanization, energy consumption, and CO_2 emissions: A regional analysis in China. Energy Policy, 49, 488-498.
Zhu, J., Huang, Z., Li, Z., & Albitar, K. (2021). The Impact of Urbanization on Energy Intensity—An Empirical Study on OECD Countries. Green Finance, 3(4), 508-526.

List of Developing Countries

Countries Names (32)	
Afghanistan	Japan
Bangladesh	Kiribati
Bhutan	Korea, Rep.
India	Malaysia
Maldives	Mongolia
Nepal	Nauru
Pakistan	New Caledonia
Sri Lanka	Behrain
American Samoa	Papua New Guinea
Turkey	Philippines
Cambodia	Singapore
China	Thailand
Fiji	Timor-Leste
French Polynesia	Tonga
Guam	Vanuatu
Indonesia	Vietnam