Journal of Infrastructure, Policy and Development (2023) Volume 7 Issue 3.
DOI: 10.24294/jipd.v7i3.2166

ORIGINAL ARTICLE

Impact of financial development, energy consumption and urbanization on CO_2 emissions from buildings using quantile ARDL model

***Seema Rehman*[1], *Saif Ullah*[2,*], *Fahad Azim*[3], *Haroon Ur Rashid Khan*[4]**

[1] *Department of Business Administration—KASBIT, Karachi 74400, Pakistan*

[2] *Department of Management Technology, Information Science, ZUFESTM, Ziauddin University, Karachi 74700, Pakistan*

[3] *ZUFESTM, Ziauddin University, Karachi 74700, Pakistan*

[4] *University of Wollongong in Dubai, Dubai 20183, United Arab Emirates*

ABSTRACT

Urbanization plays a crucial role in facilitating the integration of population growth, industrial development, economic expansion, and energy consumption. In this paper, we aim to examine the relationships between CO_2 emissions and various factors including economic growth, urbanization, financial development, and energy consumption within Pakistan's building sector. The study utilizes annual data spanning from 1990 to 2020. To analyze the cointegration relationship between these variables, we employ the quantile autoregressive distributed lag error correction model (QARDL-ECM). The findings of this research provide evidence supporting the presence of an asymmetric and nonlinear long-term relationship between the variables under investigation. Based on these results, we suggest the implementation of tariffs on nonrenewable energy sources and the formulation of policies that promote sustainable energy practices. By doing so, policymakers and architects can effectively contribute to minimising environmental damage. Overall, this study offers valuable insights that can assist policymakers and architects in making informed decisions to mitigate environmental harm while fostering sustainable development.

KEYWORDS

QARDL-ECM; CO_2 emission; economic growth; urbanization; energy consumption; financial development; Pakistans

ARTICLE INFO
Received: 30 May 2023
Accepted: 31 July 2023
Available online: 11 October 2023

*CORRESPONDING AUTHOR
Saif Ullah, Department of Management Technology, Information Science, ZUFESTM, Ziauddin University, Karachi 74700, Pakistan; Saifullah_142@yahoo.com

CITATION
Rehman S, Ullah S, Azim F, Khan HUR (2023). Impact of financial development, energy consumption and urbanization on CO_2 emissions from buildings using quantile ARDL model. *Journal of Infrastructure, Policy and Development* 7(3): 2166. doi: 10.24294/jipd.v7i3.2166

1. Introduction

The increasing trend of environmental deterioration and the depletion of global resources prompted academics and policymakers to identify environmental degradation-causing factors. Numerous studies have evaluated the extent of environmental pollution by considering a variety of variables, including CO_2 emission, a substantial greenhouse gas (GHG) that plays a crucial role in climate change and global warming (Godil, Sharif, et al., 2020; Ullah et al., 2018). Maintaining a constant level of CO_2 emissions is one of the key objectives of contemporary practices and research, which seeks to reduce CO_2 emissions to enhance the quality of life on Earth. According to the German Watch Report of 2019, Pakistan has been the fifth most affected country by climate change over the last 20 years (Tanveer et al., 2021). Economic expansion, the influx of FDI, the development of the financial sector, and energy use are significant environmental quality determinants (H. Khan, Liu, and Khan, 2022a).

Energy consumption is vital in emerging economies including Pakistan, where the population is overgrowing. The growing price of petroleum widens the global gap between energy demand and supply. Though gas and electricity have high demand, the energy source oil has attracted more attention in previous decades. In light of increasing oil costs, alternative energy sources such as wind, nuclear, and solar are recommended to ensure low-cost energy production for economic growth (Jamil, 2022). There are two possible theories for economic growth's contribution to environmental pollution. First, according to Sarkodie and Strezov (2019), economic expansion increases the extraction of natural resources, which leads to garbage dumping. Technological advances control strict environmental rules and offer a framework for economic development that encourages pollution-intensive businesses to relocate into the services sector, ultimately lowering environmental pollution. According to Panayotou (1993), fostering economic development necessitates using materials in production and consumption activities, which adds to environmental pollution.

Moreover, excessive resource consumption for mining, deforestation, and industrialization hurts environmental quality. Integrating sustainable management practices with production and consumption processes reduces the depletion rate of natural resources, allowing for their subsequent regeneration. Second, economic development necessitates high demand and energy consumption, influencing atmospheric emissions. Energy consumption, particularly fossil fuel, is viewed as the primary cause of greenhouse gas emissions (H. Khan, Khan, and BiBi, 2022). Research implies that the economic theory suggests better economic development by overflowing while contributing to climate change. According to a study by H. Khan, Liu, and Khan (2022c), enhancing financial development reduces CO_2 emissions and boosts economic development. At the same time, consumption of renewable energy mitigates both of these effects. ICT hurts CO_2 emission (e.g., H. Khan, Liu, and Khan, 2022b) while also considering financial development and economic growth, using two indicators of ICT, namely fixed broadband and mobile cellular subscription. In the presence of ICT, innovation and using renewable energy reduced CO_2 emissions, while fixed telephone subscriptions and trade openness increased them. Thus, the rise of ICT, financial development, and innovation can improve environmental quality. Sustainable economic development has reached a central position in the majority of nations. The increased economic activity due to a surge in production increases energy demand, resulting in CO_2 emissions. Adopting innovations that improve energy efficiency and obtaining sources of renewable energy that can be used for manufacturing can lead to sustainable development. With one exception, research by I. Khan, Han, et al. (2022a) indicates that innovation indices improve environmental quality. International trade and renewable energy enhance environmental quality whole economic growth, and FDI enhances CO_2 emissions and environmental degradation. Ahmad et al. (2019) remark that substantial demand for buildings and infrastructure typically accompanies rapid urbanization. Consequently, construction considerations should also be considered while evaluating urbanization. The Pakistani population is expected to expand by approximately 59% by 2050, according to the World Bank's (2019) estimate. Although there is a correlation between urbanization and economic growth, the government faces more obstacles in providing homes and disposing of waste. Bhutto et al. (2011) demonstrate that natural gas and liquefied petroleum gas (LPG) is the most used cooking fuels in metropolitan regions of Pakistan. Due to limited financial resources, however, biomass fuels constitute the primary energy source in rural areas. The Intergovernmental Panel on Climate Change does not include emissions from biomass fuels in its list of contributions to greenhouse gases (IPCC). Pakistan's home sector consumes a disproportionately large amount of electricity compared to other industries (Mir et al., 2017).

In 2019, the direct CO_2 emissions connected to heating and cooking from Pakistan's building sector amounted to 10% of total CO_2 emissions. In addition, the construction industry was accountable for 15% of CO_2 emissions from power usage. Direct CO_2 emissions from buildings result from fuel used for heating and cooking, whereas indirect CO_2 emissions occur from electricity use for air conditioning, home appliances, etc. From 2009 to 2019, Pakistan's construction sector consistently contributed between 10% and 15% of total CO_2 emissions. Since 2015, Pakistan's CO_2 emissions have increased substantially, as have building emissions. The energy-related CO_2 emissions by sector are presented in **Figure 1**.

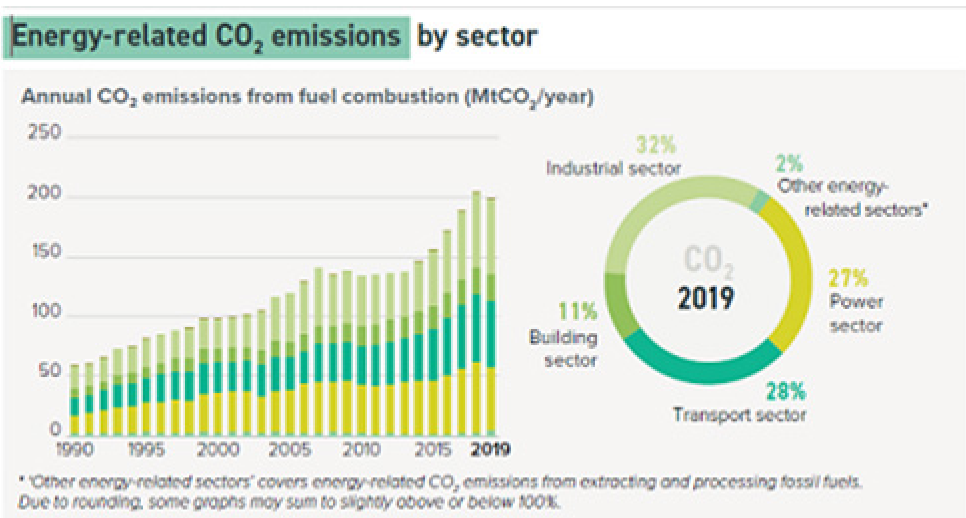

Figure 1. Energy related CO_2 emission.
Source: Enerdata.

Energy usage is a significant contributor to environmental degradation. Global fossil fuels consumption to meet energy needs is one cause of environmental degradation (Kasman and Duman, 2015; Koçak and Şarkgüneşi, 2017). According to Ocal and Aslan (2013), the increasing demand for fossil fuels would harm the ecosystem and deplete them. Sultan et al. (2018) state that urbanization and industrial expansion constantly increase energy demand. It is anticipated to triple by 2050, as Pakistan is widely recognized as a quickly developing economy. Pakistan belongs to the group of nations where the building sector consumes the most energy (55%) compared to sophisticated economies such as China (20%), the United States (39%), and Canada (27%) (Amber et al., 2021).

Several economies have adopted alternative energy sources to reduce fossil fuel consumption (Toklu, 2013). Raheem et al. (2016) assert that limited efforts have been made to sustainable energy resources. Aziz et al. (2020) suggest that because the sustainable growth of any nation depends on a sustainable environment, regulatory agencies should be aware of the contributions of each industry to environmental pollution.

Many academics consider financial development a crucial determinant of environmental degradation (e.g., Le and Ozturk, 2020). Financial development increases FDI, which ultimately increases GDP and requires more production of energy. Financial development creates a credit culture in the economy that requires greater energy use, resulting in environmental degradation (H. Khan, Han, and Khan, 2022c). Some authors argue that financial development promotes clean technologies by focusing regulatory authorities' attention on a sustainable environment throughout the financial development process (Cole and Elliott, 2005; Godil, Sharif, et al., 2020). Usman et al. (2020) state that financial development promotes loans, bonds, promissory notes, and leasing operations, reducing CO_2 emissions and resource consumption. Ghafoor et al. (2020) found that the seldom use of roof insulation in the building industry indicates the need for energy audits and appropriate measures to promote energy conservation.

There needs to be more research on CO_2 emissions from Pakistan's urban building sector. This study aims to address this deficiency by examining the relationships between building CO_2 emission (CO_2_BUILD), gross domestic product (*GDP*), urbanization (*URB*), energy consumption for the building sector (*ENR_BUILD*), and financial development (*FD*). Using the quantile autoregressive distributive lag (QARDL) model, this study is the first to examine CO_2 emissions from Pakistan's construction industry. It can capture the asymmetric impacts of variables of interest on building CO_2 emission, giving regulatory authorities and law-making agencies fresh insights for formulating policies conducive to reducing CO_2 emission.

The remainder of the paper is structured as follows. Section 2 examines the available literature. Section 3 gives the data and methodology, Section 4 discusses data analysis and findings, and Section 5 provides a conclusion.

2. Literature review

The importance of climate change, global warming, and CO_2 emissions to environmental sustainability and economic growth cannot be overstated. However, several researchers have shown an inverse relationship between CO_2 emissions and a sustainable ecosystem, making this a contentious and hotly contested topic (S. P. Nathaniel and Adeleye, 2021; Yousaf and Lin, 2020). Khan, Liu, et al. (2022) explored the role of income disparity in CO_2 emissions. Therefore, global debaters employ many strategies for CO_2 emissions reduction and the goal of achieving a low-carbon economy. CO_2 emission from energy usage and identifying the variables driving this phenomenon is paramount (Ma et al., 2019). Maintaining a sustainable environment is essential for every nation's economic prosperity. Therefore, regulatory agencies should be aware of the causes of environmental pollution (Aziz et al., 2020). Adebanjo and Adeoye (2022) examined that transparency is a global phenomenon that aims to eradicate corruption, ensure accountability, and assist nations in developing budgets that provide their population with a high standard of life. Evidence of a considerable relationship exists between GDP, inflation, and the transparency metric. According to the study of Jamil et al. (2022), Pakistani businesses could build a sustainable environmental framework by fostering employee self-efficacy and performance-based bonuses. A company can succeed by addressing employee needs and Corporate Social Responsibility. Adebanjo and Adeoye (2022) claimed that the long-term relationship between air pollution and economic growth exists. According to I. Khan, Han, et al. (2022b), in recent years, the primary concern of most economies has been accelerating economic development to enhance living standards. Nevertheless, the corresponding energy demand increases CO_2 emissions. They investigate the influence of innovation and renewable energy usage and their impact on CO_2 emissions reduction in OECD nations from 2004 to 2019. Economic growth and innovation positively impact CO_2 emissions, whereas renewable energy improves environmental quality. Cristobal-Cipriano et al. (2022) investigate Corporate Social Responsibility (CSR) programs using the Triple Bottom Line structure of sustainability, i.e., Planet, People and Profit. Customer happiness and corporate reputation are the primary drivers of corporate social responsibility, according to the findings of Weili et al. (2022). ICT, financial development, energy consumption and economic development increase CO_2 emissions, whereas renewable energy use and worldwide commerce decrease it.

Urbanization and energy consumption in the building sector have piqued the interest of academics and policymakers conducting macro and micro-level theoretical and empirical research into the underlying causes. At the macro level, economic growth, urbanization, and new technologies contribute to the building sector's energy use (Sun et al., 2014). Li (2018) considers price, climate change, and trading laws as additional indicators. Besagni and Borgarello (2018) mention building structure, household characteristics, and electrical devices as micro-level determinants. Recent research in the building industry focuses on energy efficiency, rebound effects, environment Kuznets curves (EKC), and thermal retrofits for low-income families (e.g., Galvin and Sunikkablank, 2013; Pablo-Romero and Sanchez-Braza, 2017; Sorrell, 2009; Wen et al., 2018). Using varying degrees of data, empirical researchers have identified the variables responsible for CO_2 emission and energy consumption in the building sector. However, according to Wang and Zhao (2015), the most influential factors in building CO_2 emissions are the rise of the GDP, population, and urbanization. This evidence is provided by the theory of urban environmental transition, which states that increasing wealth and urbanization will increase CO_2 emissions from buildings due to the rising demand for energy to power household electronic appliances, building heating systems, and transportation (Poumanyvong and Kaneko, 2010).

Using panel data from developed nations, Liddle (2010) concludes that urbanization affects building CO_2 emissions. Regionally, Poumanyvong et al. (2012) investigate the relationship between CO_2 emissions from buildings and urbanization. Sohag et al. (2015) investigate if household consumption impacts Malaysia's CO_2 emission level. Maraseni et al. (2015) compare the CO_2 building emissions of China, Canada, and the United Kingdom. Per capita CO_2 emissions of China are lower than those of Canada and the United Kingdom. To reduce CO_2 emissions from buildings, they advocate using hydroelectric and nuclear energy for central heating. Das and Paul (2014) use the input-output model to evaluate the primary variables influencing CO_2 emissions from buildings in India. Yuan et al. (2015) use the input-output approach at the national level to analyze the impact of urbanization, household spending, and spending framework on building CO_2 emission in China, identifying urbanization and spending framework as the two most important variables indirectly responsible for building CO_2 emission. Using regional-level data from the United States, Lee and

Lee (2014) developed a structural equation modeling (SEM) approach to analyze the impact of urbanization on building CO_2 emissions. Their findings indicate that doubling the population-weighted density reduces building CO_2 emissions from energy use by 35%. They also demonstrate the significant importance of innovative growth strategies in reducing CO_2 emissions from buildings (Miao et al., 2019).

Existing research indicates a two-way relationship between consumption of energy and CO_2 emissions (e.g., Soytas and Sari, 2009). For example, increased energy use increases CO_2 emissions and environmental deterioration. CO_2 emissions and financial growth significantly impact environmental sustainability. Soytas et al. (2007) contend that economic expansion leads to technological progress, eventually reducing CO_2 emissions. Numerous research investigates the connection between economic growth and CO_2 emissions (e.g., S. P. Nathaniel and Adeleye, 2021). Some find a beneficial influence of capital formation on CO_2 emission mitigation (Akalpler and Hove, 2019; Zubair et al., 2020), while others discover a direct link between the two elements, such as more financial development causing an escalation in CO_2 emissions (Godil, Ahmad, et al. (2021), Godil, Sharif, et al. (2020), and Shahzad et al. (2017) for Pakistan). Le and Ozturk (2020) indicate a positive correlation for emerging economies. This leads to the conclusion that financial development raises CO_2 emissions if the economies do not respect environmental norms while building industries (Tanveer et al., 2021).

Globally, initiatives to limit CO_2 emissions to counteract environmental pollution are evident as urbanization continues. For example, United Nations Framework Convention on Climate Change (UNFCCC) established a primary structure for international collaboration (Zhang et al., 2017). Afterward, pledges to limit CO_2 emissions are adopted by additional countries during Kyoto Protocol and Paris Agreement (Chen et al., 2019). Researchers propose several methods for reducing CO_2 emissions by implementing renewable energy and eco-friendly activities. According to a study by S. A. R. Khan et al. (2018), regulatory agencies should foster green industrial development by establishing enabling regulations. S. Nathaniel and Khan (2020) advocate using sustainable energy to balance environmental deterioration and economic growth. Moreover, Shen et al. (2018) recommend that metropolitan communities change their approach to economic growth and prioritize speed and quality even though global steps are made to minimize CO_2 emissions. Lin and Liu (2020) report that the CO_2 emissions of several significant energy-consuming businesses, such as the construction industry, have remained the same and have increased.

Based on the above literature, economic growth, financial development, urbanization and energy consumption on CO_2 from building in Pakistan. The theoretical framework can be developed as follow in **Figure 2**.

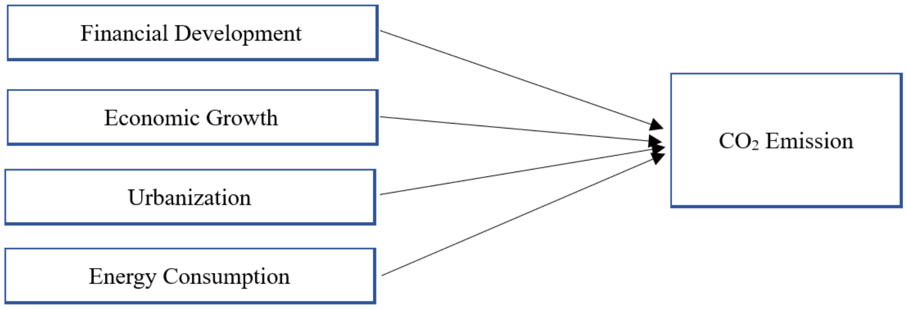

Figure 2. Theoretical framework.

3. Methodology

3.1. Data

From 1990 to 2020, annual data on the dependent and independent variables for the Pakistani construction industry were utilized. Using the makima's interpolation technique, year data are transformed into quarterly observations. Carbon dioxide (CO_2) emitted by the construction sector (percentage of total fuel burning) is used to assess the quality of the environment. GDP per capita (current US dollars) indicates a nation's economic growth (e.g., Godil, Sharif, et al., 2020). Urbanization is illustrated by the Urban population growth (annual %). The International Energy Agency provides residential, business, and public service energy consumption in kilotons of oil (e.g., Tanveer et al., 2021). Financial development is measured through the ratio of domestic credit to the private sector to GDP (e.g., Tanveer et al., 2021). The World Development Indicators include data on the gross domestic product, urbanization, and financial development. **Table 1** explains the measurement of the variables employed in this investigation.

Table 1. Variables used in this research, symbols, descriptions, and data sources.

Variable	Symbol	Description	Data source
Carbon emission	CO_2_BUILD	CO_2 from the building	CAIT, world resources institute
Gross domestic product	*GDP*	GDP per capita (current US$)	World Bank
Urbanization	*URB*	Urban population growth (annual %)	World Bank
Energy consumption	*ENR_BUILD*	Energy consumption for residential and commercial, and public services includes coal, oil, bio-fuels, electricity and natural gas (kiloton of oil equivalent)	International Energy Agency
Financial development	*FD*	Domestic credit to the private sector	World Bank

3.2. Research design

This research applies the quantile autoregressive distributed lag (QARDL) proposed by Cho et al. (2015) to evaluate the cointegrated link among building CO_2 emission, urbanization, GDP, energy consumption by buildings and financial growth in Pakistan (e.g., Aziz et al., 2020; Godil, Sharif, et al., 2020). This method extends the ARDL model and permits the researcher to study the long-run equilibrium impact of explanatory variables on response variables at various quantiles. Due to the time-varying nature of integrated relationships, the consistency of estimated parameters can also be examined using the Wald test over quantiles. This can be written as the equation:

$$CO_2\_BUILD_t = \mu + \sum_{i=1}^{p} \upsilon_{CO_2\_BUILD_i} CO_2\_BUILD_{t-i} + \sum_{i=0}^{q} \upsilon_{GDP_i} GDP_{t-i} + \sum_{i=0}^{r} \upsilon_{GDP_i^2} GDP_{t-i}^2 + \sum_{i=0}^{s} \upsilon_{URB_i} URB_{t-i} + \sum_{i=0}^{u} \upsilon_{ENR\_BUILD_i} ENR\_BUILD_{t-i} + \sum_{i=0}^{v} \upsilon_{FD_i} FD_{t-i} + \varepsilon_t \quad (1)$$

where ε_t stands for $CO_2\_BUILD_t - E[\frac{CO_2\_BUILD_t}{\lambda_{t-1}}]$, and λ_{t-1} presents the smallest possible yielded by $\{CO_2\_BUILD_t, GDP_t, GDP_t^2, URB_t, ENR\_BUILD_t, FD_t, CO_2\_BUILD_{t-i}, GDP_{t-i}, GDP_{t-i}^2, URB_{t-i}, ENR\_BUILD_{t-i}, FD_{t-i}\}$. Bayesian (Schwarz) information criterion (BIC) is used to determine the lag orders *p*, *q*, *r*, *s*, *u* and *v*. CO_2_BUILD, GDP, GDP^2, *URB*, *ENR_BUILD* and *FD* present building CO_2 emission, gross domestic product and its square, building sector consumption of energy, and financial growth.

Quantile context of Cho et al. (2015), Equation (1) may be extended as follows:

$$Q_{CO_2\_BUILD_t} = \mu(\tau) + \sum_{i=1}^{p} \upsilon_{CO_2\_BUILD_i}(\tau) CO_2\_BUILD_{t-i} + \sum_{i=0}^{q} \upsilon_{GDP_i}(\tau) GDP_{t-i} + \sum_{i=0}^{r} \upsilon_{GDP_i^2}(\tau) GDP_{t-i}^2 + \sum_{i=0}^{s} \upsilon_{URB_i}(\tau) URB_{t-i} + \sum_{i=0}^{u} \upsilon_{ENR\_BUILD_i}(\tau) ENR\_BUILD_{t-i} + \sum_{i=0}^{v} \upsilon_{FD_i}(\tau) FD_{t-i} + \varepsilon_t(\tau) \quad (2)$$

where $\varepsilon_t(\tau) = CO_2\_BUILD_t - Q_{CO_2\_BUILD_t}(\frac{\tau}{\delta_{t-1}})$ and quantile falls within the range $0 > \tau < 1$.

For the possibility of serial correlation in $\varepsilon_t(\tau)$, Equation (2) might be rewritten as follows:

$$Q_{\Delta CO2\_BUILD_t} = \mu + \rho CO_2\_BUILD_{t-1} + \kappa_{GDP} GDP_{t-1} + \kappa_{GDP^2} GDP_{t-1}^2 + \kappa_{URB} URB_{t-1} + \kappa_{ENR\_BUILD} ENR\_BUILD_{t-1} + \kappa_{FD} FD_{t-1} \sum_{i=1}^{p} + \upsilon_{CO_2\_BUILD_i}(\tau) CO_2\_BUILD_{t-i} + \sum_{i=0}^{q} \upsilon_{GDP_i} \Delta GDP_{t-i} + \sum_{i=0}^{r} \upsilon_{GDP_i^2} \Delta GDP_{t-i}^2 + \sum_{i=0}^{s} \upsilon_{URB_i} \Delta URB_{t-i} + \sum_{i=0}^{u} \upsilon_{ENR\_BUILD_i} \Delta ENR\_BUILD_{t-i} + \sum_{i=0}^{v} \upsilon_{FD_i} \Delta FD_{t-i} + \varepsilon_t(\tau) \quad (3)$$

In accordance with Cho et al. (2015), the QARDL ECM reparameterization model could be adjusted as follows:

$$Q_{\Delta CO_2\_BUILD_t} = \mu(\tau) + \rho(\tau)(CO_2\_BUILD_{t-1} - \beta_{GDP}(\tau) GDP_{t-1} - \beta_{GDP^2}(\tau) GDP_{t-1}^2 - \beta_{URB}(\tau) URB_{t-1} - \beta_{ENR\_BUILD}(\tau) ENR\_BUILD_{t-1} - \beta_{FD}(\tau) FD_{t-1}) + \sum_{i=1}^{p} \upsilon_{CO_2\_BUILD_i}(\tau) \Delta CO_2\_BUILD_{t-i} + \sum_{i=0}^{q} \upsilon_{GDP_i}(\tau) \Delta GDP_{t-i} + \sum_{i=0}^{r} \upsilon_{GDP_i^2}(\tau) \Delta GDP_{t-i}^2 + \sum_{i=0}^{s} \upsilon_{URB_i}(\tau) \Delta URB_{t-i} + \sum_{i=0}^{u} \upsilon_{ENR\_BUILD_i}(\tau) \Delta ENR\_BUILD_{t-i} + \sum_{i=0}^{v} \upsilon_{FD_i}(\tau) \Delta FD_{t-i} + \varepsilon_t(\tau) \quad (4)$$

In the short run, *CO_2_BUILD* represents the cumulative effect of previous *CO_2_BUILD* on current levels as measured by the delta technique. Similarly, the cumulative short-term effects of *υCO_2_BUILD* past and present *GDP*, *URB*, *ENR_BUILD*, and *FD* are illustrated. *CO_2_BUILD* is computed by *υGDP* = $\sum_{i=0}^{q} \upsilon_{GDP_i}$, $\upsilon GDP^2 = \sum_{i=0}^{r} \upsilon_{GDP_i^2}$, *υURB* = $\sum_{i=0}^{s} \upsilon_{URB_i}$, *υENR_BUILD* = $\sum_{i=0}^{u} \upsilon_{ENR\_BUILD_i}$, and *υFD* = $\sum_{i=0}^{v} \upsilon_{FD_i}$. The value of ρ should be negative and significant. The betas βs long-run cointegration coefficients present long-run cointegrating coefficients of *GDP*, GDP^2, *URB*, *ENR_BUILD* and *FD* and are computed as follows:

βGDP = *–βGDP/ρ*, $\beta GDP^2 = -\beta GDP^2/\rho$, *βURB* = *–βURB/ρ*, *βENR_BUILD* = *–βENR_BUILD/ρ*, *βFD* = *–βFD/ρ*.

The Wald test tests the short-run and long-run asymmetries in this study, such as the null hypothesis for the coefficient of the speed of adjustment ρ is: ρ (0.05) = ρ (0.15) = ρ (0.95) and the same hypothesis is used for testing long-run parameters *βGDP*, *βURB*, *βENR_BUILD*, *βFD* and short-run parameters *υGDP*, *υURB*, *υENR_BUILD*, and *υFD*.

3.3. Data analysis and findings

The descriptive statistics of the variables employed in this investigation are presented in **Table 2**. The data for financial development is negatively skewed, indicating a longer right tail for financial development. However, the other variables indicate positive skewness. The Jarque-Bera statistics further confirm the non-normal distribution for variables under study. The non-normality of data is an essential quality to moving toward employing quantile regression models (Mishra et al., 2019). **Table 3** contains the results of the Augmented Dickey-Fuller (ADF) and Phillips Perron tests for checking unit roots. The ARDL model requires that all variables are either stationary at levels or first differences, such that the order of integration is I(0) or I(1).

Table 2. Findings of summary statistics.

Variables	CO_2_BUILD	GDP	URB	ENR	FD
Mean	14.111	834.163	3.066	1.3888×10^6	21.756
Minimum	7.61	371.679	2.65	873,013	15.366
Maximum	21.7	1491.15	3.773	1.98864×10^6	28.734
Std. Dev.	4.413	366.662	0.391	338,092	3.87
Skewness	0.216	0.348	0.521	0.208	–0.135
Kurtosis	1.679	1.595	1.609	1.83	1.756
Jarque-Bera	9.739	12.402	15.225	7.775	8.162
Probability	0.017	0.010	0.006	0.026	0.024

Source: Author's estimation.

Table 3. Results of unit root analyses.

Variables	Level		First difference	
	ADF	PP	ADF	PP
CO_2_BUILD	6.817	6.817	–2.722***	–2.722***
GDP	3.397	3.397	–2.324***	–2.324***
URB	–4.119***	–4.119***	–1.862*	–1.862*
ENR-BUILD	–2.328***	–2.328***	–2.730***	–2.730***
FD	–1.277	–1.277	–3.066***	–3.066***

*Note: *, ** and *** stand for 10%, 5% and 1%, respectively.*

Table 4 contains the estimation findings for QARDL. The values for the estimated parameter of dependency ρ are negative at all quantiles and highly significant (with one exception) at a 1% level of significance, demonstrating a decline to a long-term equilibrium of nexus between *CO_2_BUILD* and *GDP*, *GDP^2*, *URB*, *ENR_BUILD* and *FD*. Except for the final three extreme quantiles, the coefficients for *GDP* are positive at a 1% significance level for practically all quantiles, i.e., 0.05–0.7. Lower quantiles show negative yet statistically significant values. With rare exceptions, the URB values exhibit a similar upward trend as the *GDP* parameters, indicating a positive link with building CO_2 emissions. It implies that building CO_2 emissions can be stretched as an effect of increased urbanization. The long-term cointegrating parameter *ENR_BUILD* demonstrates that building CO_2 emission has a large positive connection with energy consumption for the building industry in Pakistan, indicating that rising consumption of energy hurt environment (Tanveer et al., 2021). Except at extreme quantiles, the *FD* coefficients reveal a negative and statistically significant link between building CO_2 emissions and *FD*. The country's CO_2 emissions from construction are now lower and will continue to fall as its economic development advances. Zakaria and Bibi (2019) and Godil, Sharif, et al. (2020) reach the same conclusions on global CO_2 emissions.

Turning to short-term factors, it is evident that past CO_2 emission levels benefit their current counterparts at all quantiles. However, the current and historical changes in GDP and its square

Table 4. Quantile autoregressive distributed lag (QARDL) outcomes for *CO_2_BUILD*.

Quantiles (τ)	$\mu^*(\tau)$	$\rho^*(\tau)$	$\beta GDP(\tau)$	$\beta GDP^2(\tau)$	$\beta URB(\tau)$	$\beta ENR\_BUILD(\tau)$	$\beta FD(\tau)$	υCO_2_BUILD	υGDP	υGDP^2	υURB	υENR_BUILD	υFD
0.05	–2.2866***	–0.0832***	0.1274***	–0.0637***	4.6596***	0.1629***	–0.0714***	0.9943***	–0.0065	0.0046	–1.7732***	0.0394*	0.0096
	(–7.122)	(–4.84)	(6.106)	(–5.656)	(6.328)	(15.913)	(–4.723)	(18.128)	(–0.698)	(1.016)	(–4.339)	(1.763)	(1.093)
0.10	–2.3629***	–0.0886***	0.1308***	–0.0626***	4.5944***	0.1569***	–0.0725***	0.9983***	–0.0018	0.0029	–1.7527***	0.0318	0.0134
	(–5.818)	(–7.526)	(4.781)	(–4.499)	(6.936)	(15.696)	(–4.123)	(21.988)	(–0.2)	(0.71)	(–3.622)	(1.61)	(1.043)
0.20	–2.5171***	–0.1016***	0.1282***	–0.0574***	4.3907***	0.1472***	–0.073***	1.0397***	0.0073	–0.0012	–2.1514***	0.023	0.0153*
	(–14.088)	(–8.916)	(7.504)	(–6.633)	(11.054)	(23.79)	(–5.839)	(26.463)	(1.308)	(–0.445)	(–6.387)	(1.624)	(1.906)
0.30	–2.3909***	–0.0903***	0.1416***	–0.0648***	4.6962***	0.1488***	–0.081***	1.0439***	0.0026	–0.0001	–2.3078***	0.0409***	0.0219***
	(–8.417)	(–9.444)	(7.968)	(–6.783)	(9.952)	(25.442)	(–5.917)	(35.365)	(0.524)	(–0.023)	(–7.353)	(3.026)	(3.228)
0.40	–2.1696***	–0.0827***	0.1371***	–0.0603***	4.5684***	0.1476***	–0.0534***	1.0487***	0.0029	–0.0002	–2.2464***	0.0145***	0.0177***
	(–9.265)	(–6.277)	(6.098)	(–5.794)	(9.661)	(21.349)	(–3.593)	(31.978)	(0.577)	(–0.089)	(–6.36)	(1.016)	(2.581)
0.50	–1.8915***	–0.0596***	0.1659***	–0.0751***	5.537***	0.157***	–0.0481**	0.9895***	–0.0046	0.0025	–1.7326***	0.0149	0.0215***
	(–7.15)	(–5.049)	(6.179)	(–5.791)	(7.839)	(15.82)	(–2.03)	(31.972)	(–1.02)	(1.039)	(–5.761)	(0.92)	(3.412)
0.60	–2.099***	–0.0623***	0.1727***	–0.08***	5.9992***	0.1625***	–0.0747***	0.9345***	0.0059	–0.0015	–1.7976***	0.0421**	0.0194***
	(–8.265)	(–5.974)	(8.361)	(–7.637)	(9.464)	(17.848)	(–4.566)	(29.317)	(1.23)	(–0.673)	(–5.968)	(2.497)	(3.564)
0.70	–2.0907***	–0.0644***	0.1829***	–0.0799***	5.7839***	0.1516***	–0.0556***	0.9402***	0.0115*	–0.0043	–1.9817***	0.0255	0.0245***
	(–10.245)	(–6.163)	(8.31)	(–6.984)	(7.964)	(13.253)	(–2.931)	(29.116)	(1.673)	(–1.378)	(–5.709)	(1.237)	(3.852)
0.80	–1.7644***	–0.0399***	0.2686	–0.1222	8.0315	0.1633	–0.0882	0.8713***	0.0067	–0.0024	–1.365***	0.0481***	0.0283***
	(–6.861)	(–2.664)	(0.842)	(–0.708)	(0.708)	(1.213)	(–0.887)	(19.832)	(0.805)	(–0.665)	(–2.784)	(2.713)	(3.311)
0.90	–2.1515***	–0.0321*	0.3758	–0.1938	11.8459	0.2211	–0.1289	0.8195***	0.0014	–0.0003	–1.0281*	0.0964***	0.0418***
	(–6.813)	(–1.932)	(0.071)	(–0.056)	(0.068)	(0.085)	(–0.103)	(12.581)	(0.166)	(–0.075)	(–1.755)	(3.237)	(4.734)
0.95	–2.2321***	–0.0357***	0.3491	–0.1727	11.3304	0.2106	–0.1057	0.855***	0.0128	–0.0024	–1.267***	0.036	0.0445***
	(–7.41)	(–2.693)	(0.025)	(–0.022)	(0.02)	(0.027)	(–0.014)	(15.162)	(1.018)	(–0.473)	(–2.669)	(1.142)	(5.563)

*The table displays the estimation results for QARDL. The t-statistics are enclosed within brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.*
Source: Author's estimation.

variable lose their significance in the short term. In addition, the current and previous changes in urbanization reverse sign in the short run, even though the values are still significant, which makes sense given that this study uses population growth of urban areas (annual %) for urbanization and not urban population (percent of the total population). The current and past dynamics of the consumption of energy for buildings keep their positive sign but demonstrate the relevance for the medium (0.3–0.4) and upper (0.8–0.9) quantiles in the short term. At quantiles 0.3–0.95, the current and previous financial development adjustments continue to strongly impact present building CO_2 emissions. The findings provided in **Table 4** for the cointegrated QARDL model are supported by **Figures 3–6**.

The Wald test aids in determining the stability of quantile coefficients. In addition to detecting nonlinearities in long- and short-term parameters, the Wald test estimates locational asymmetries (Cho et al., 2015). The Ho is accepted when the relationship between response and explanatory factors does not exhibit a substantial asymmetric and nonlinear trend. As indicated in **Table 5**, the Wald test statistics confirm the asymmetric and dynamic influence of short-term and long-term effects of economic expansion, urbanization, consumption of energy, and *FD* on CO_2 emission in Pakistan's building sector. **Table 5** provides sufficient evidence to reject the Ho that no nonlinearities and asymmetries across quantiles are investigated for the adjustment speed parameter. Similarly, the Wald test statistics' results reject the Ho for all explanatory variables across quantiles in the association over the long term. This indicates that the cointegrating parameters between *CO_2_BUILD* and the variables of interest, namely *GDP*, *GDP^2*, *URB*, *ENR_BUILD*, and *FD*, are significant.

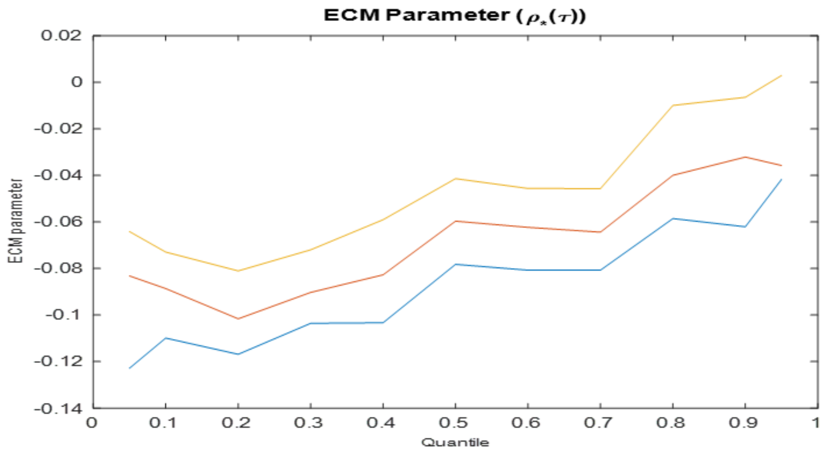

Figure 3. Error correction term ρ through quantiles.

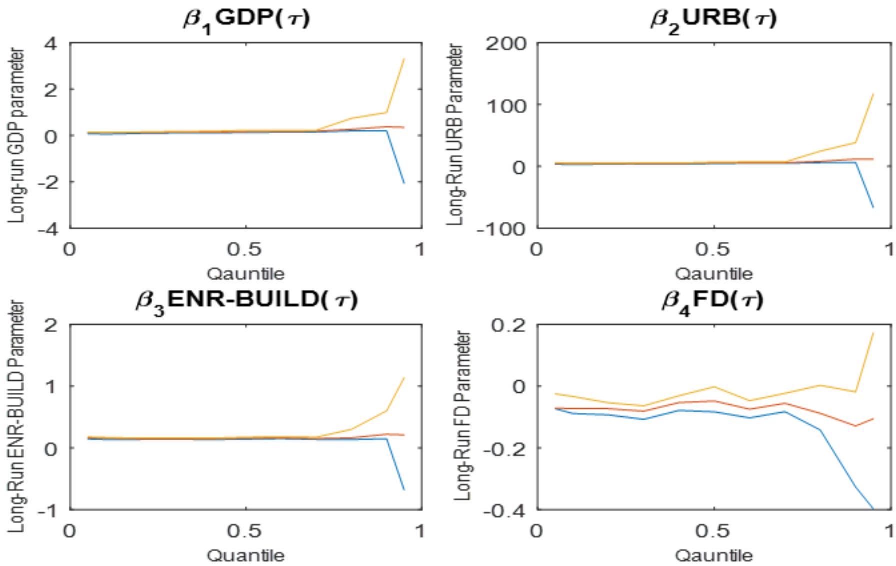

Figure 4. Long-run parameters β.

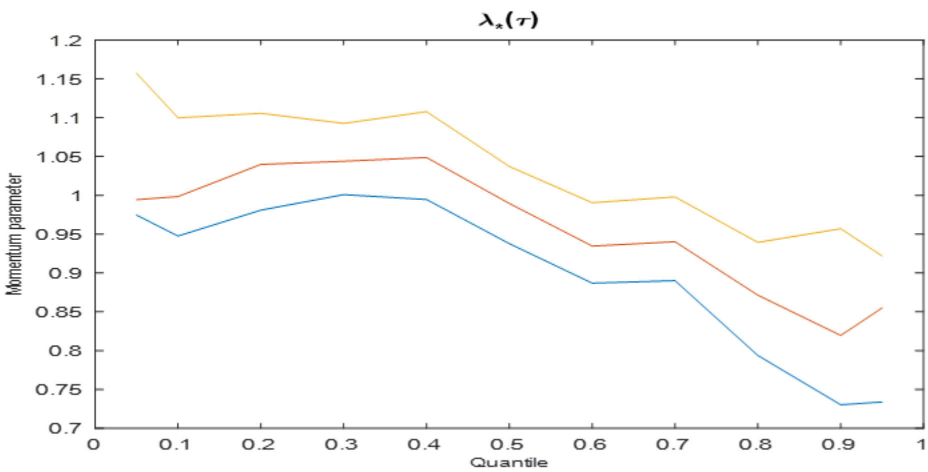

Figure 5. Previous and present increases in building CO_2 emission levels.

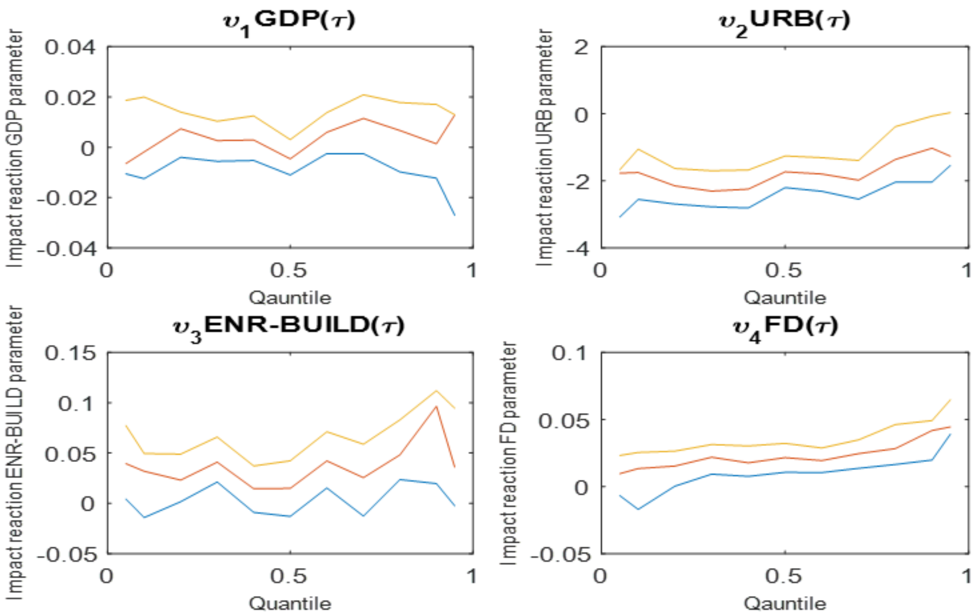

Figure 6. Short run parameters spanning quantiles.

Table 5. Results of the Wald test for the consistency of parameters.

Variables	*F*-statistics (*P*-value)
$\rho*(\tau)$	9.097*** (0.000)
$\beta GDP(\tau)$	15.285*** (0.000)
$\beta GDP^2(\tau)$	21.721*** (0.000)
$\beta URB(\tau)$	17.813*** (0.000)
$\beta ENR\_BUILD(\tau)$	8.020*** (0.000)
$\beta FD(\tau)$	14.144*** (0.000)
υCO_2_BUILD	4.542*** (0.003)
υGDP	0.449 (0.799)
υGDP^2	1.341 (0.511)
υURB	0.026 (0.987)
υENR_BUILD	1.171 (0.557)
υFD	3.565** (0.048)

*Within brackets are the p-values. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.*
Source: Author's estimation.

Table 5 shows results of Wald test which also rejects the Ho of parameter consistency in relation to the influence of past and present changes on CO_2_BUILD's current levels. The study fails to reject the Ho while analyzing the impact of past and present changes in short-run parameters for *GDP*, GDP^2, *URB*, and *ENR_BUILD*. Consequently, the linear and symmetric relationship between these variables in the short-term is identified. Despite this, the Wald test for *FD* rejects the Ho, which indicates that CO_2_BUILD and *FD* are associated.

4. Conclusions, recommendations and future directions

The current paper investigates asymmetries and nonlinearities in building CO_2 emissions about economic growth, urbanization, consumption of energy for the building sector, and financial development between 2019 and 2020. This study focuses on the building industry of Pakistan in a novel manner. Incorporating any potential asymmetries and nonlinearities between the *CO_2_BUILD* and *GDP*, *GDP^2*, *URB*, *ENR_BUILD* and *FD*, the recently popular econometric technique of Cho et al. (2015) used in this paper permits an instantaneous investigation of both the long- and short-term relationship. The parameter estimate is negative and statistically significant at all quantiles, as determined by the QARDL model. The link between *CO_2_BUILD* and all independent factors in the study is evident over time. Long-term increases in *GDP*, *URB*, and *ENR_BUILD* are associated with increases in *CO_2_BUILD*, but this association is minor for the last three quantiles, suggesting that at high *CO_2_BUILD* levels, *GDP*, *URB*, and *ENR_BUILD* have little effect.

Except for the final three extreme quantiles, the coefficients for *GDP* are positive in practically all quantiles, i.e., 0.05–0.7. Lower quantiles show negative yet statistically significant values. With rare exceptions, the URB values exhibit a similar upward trend as the *GDP* parameters, indicating a positive link with building CO_2 emissions. Turning to short-term factors, it is evident that past CO_2 emission levels benefit their current counterparts at all quantiles. However, the current and historical changes in GDP and its square variable lose their significance in the short term. The current and past dynamics of energy consumption for buildings keep their positive sign but demonstrate the relevance for the medium (0.3–0.4) and upper (0.8–0.9) quantiles in the short term. At quantiles 0.3–0.95, the current and previous financial development adjustments continue to strongly impact present building CO_2 emissions.

Evidence shows a significant positive relationship between economic growth, which is related to an increase in national income and building CO_2 emissions, indicating a more polluted environment due to energy conservation policies. Consequently, the Pakistani government must reduce CO_2 emissions by decreasing its reliance on coal fuels and adopting environmentally benign energy sources while maintaining economic growth. A significant benefit of using sustainable energy is that it does not contribute to the emission of harmful gases. However, sustainable energy demands a substantial investment in equipment and instruments, making it important to perform research and development to uncover low-cost alternatives for environmental protection. The findings of this study also give substantial evidence of the relationship between the environmental degradation and urbanization. According to Guan et al. (2015), urbanization is a dynamic phenomenon characterized by transferring large populations to urban areas, resulting in increased consumption of energy and CO_2 emissions from nearly all economic activity. Local governments should justify urbanization plans and formulate more sustainable and ecologically feasible communities to combat continuing urbanization. In urban growth, compactness should be emphasized, and unplanned urban development must be restrained. Utilizing energy-efficient gadgets and appliances in buildings may contribute adversely to electricity use. Modifying the architectural pattern and educating the public about energy consumption are viable alternatives for reducing electricity consumption and improving the environment.

Contrary to this, an increase in *FD* produces a drop in CO_2, as indicated by notably negative metrics. Therefore, policymakers must implement credit policies that facilitate loans to the financial sector for use in green projects that reduce CO_2 emissions. In addition, the results suggest that urbanization, economic growth, energy consumption and financial development play a crucial role in preventing environmental degradation through implementing economic and financial reforms. This study's findings aid regulatory bodies in managing urbanization growth, considering green investment, and implementing other sustainable urbanization measures to protect the public from natural disasters. The study has some limitations including only emission from building is taken while other factors are also important. Future research may include all emissions factors and make a comprehensive study.

Author contributions

Conceptualization, SR and SU; methodology, SR and SU; software, SR; validation, SU, FA and HURK; formal analysis, SR and SU; investigation, SR, SU and FA; resources, SU, FA and HURK; data curation, SR; writing—original draft preparation, SR and SU; writing—review and editing, FA and HURK; visualization, FA and HURK; supervision, FA and HURK; project administration, FA and HURK. All authors have read and agreed to the published version of the manuscript.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data and material availability

The authors agree to disclose data and methods.

Code availability

The authors agree to the disclosure of codes.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

References

Adebanjo SA, Adeoye OM (2022). Transparency and global initiatives in the face of natural resource depletion in

Sub-Saharan Africa. *Journal of Environmental Science and Economics* 1(2): 13–24. doi: 10.56556/jescae.v1i2.13

Adebanjo SA, Shakiru TH (2022). Dynamic relationship between air pollution and economic growth in Jordan: An empirical analysis. *Journal of Environmental Science and Economics* 1(2): 30–43. doi: 10.56556/jescae.v1i2.17

Ahmad M, Zhao Z, 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. doi: 10.1016/j.scitotenv.2018.12.112

Akalpler E, Hove S (2019). Carbon emissions, energy use, real GDP per capita and trade matrix in the Indian economy—An ARDL approach. *Energy* 168: 1081–1093. doi: 10.1016/j.energy.2018.12.012

Amber KP, Ahmad R, Farmanbar M, et al. (2021). Unlocking household electricity consumption in Pakistan. *Buildings* 11: 566. doi: 10.3390/buildings11110566

Aziz N, Sharif A, Raza A, et al. (2020). Revisiting the role of forestry, agriculture, and renewable energy in testing environment Kuznets curve in Pakistan: Evidence from quantile ARDL approach. *Environmental Science and Pollution Research* 27: 10115–10128. doi: 10.1007/s11356-020-07798-1

Besagni G, Borgarello M (2018). The determinants of residential energy expenditure in Italy. *Energy* 165: 369–386. doi: 10.1016/j.energy.2018.09.108

Bhutto AW, Bazmi AA, Zahedi G (2011). Greener energy: Issues and challenges for Pakistan—Biomass energy prospective. *Renewable and Sustainable Energy Reviews* 15(6): 3207–3219. doi: 10.1016/j.rser.2011.04.015

Chen S, Jin H, Lu Y (2019). Impact of urbanization on CO_2 emissions and energy consumption structure: A panel data analysis for Chinese prefecture-level cities. *Structural Change and Economic Dynamics* 49: 107–119. doi: 10.1016/j.strueco.2018.08.009

Cho JS, Kim TH, Shin Y (2015). Quantile cointegration in the autoregressive distributed-lag modeling framework. *Journal of Econometrics* 188(1): 281–300. doi: 10.1016/j.jeconom.2015.05.003

Cole MA, Elliott RJR (2005). FDI and the capital intensity of dirty sectors—A missing piece of the PH puzzle. *Review of Development Economics* 9(2–4): 530–548. doi: 10.1111/j.1467-9361.2005.00292.x

Cristobal-Cipriano CM, Arroyo J, Romualdo A (2022). Corporate social responsibility (CSR) programs in Sarangani Province: Promotion of the triple bottom line framework of sustainability. *Journal of Environmental Science and Economics* 1(2): 67–77. doi: 10.56556/jescae.v1i2.104

Das A, Paul SK (2014). CO_2 emissions from household consumption in India between 1993–94 and 2006–07: A decomposition analysis. *Energy Economics* 41: 90–105. doi: 10.1016/j.eneco.2013.10.019

Galvin R, Sunikkablank M (2013). Economic viability in thermal retrofit policies: Learning from ten years of experience in Germany. *Energy Policy* 54: 343–351. doi: 10.1016/j.enpol.2012.11.044

Ghafoor GZ, Sharif F, Khan AU, et al. (2020). Energy consumption and carbon dioxide emissions of residential buildings in Lahore, Pakistan. *Polish Journal of Environmental Studies* 29(2): 1613–1623. doi: 10.15244/pjoes/109305

Godil DI, Ahmad P, Ashraf MS, et al. (2021). The step towards environmental mitigation in Pakistan: Do transportation services, urbanization, and financial development matter? *Environmental Science and Pollution Research* 28: 21486–21498. doi: 10.1007/s11356-020-11839-0

Godil DI, Sharif A, Agha H, et al. (2020). The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO_2 emission in Pakistan: New insights from QARDL approach. *Environmental Science and Pollution Research* 27: 24190–24200. doi: 10.1007/s11356-020-08619-1

Guan X, Zhou M, Zhang M (2015). Using the ARDL-ECM approach to explore the nexus among urbanization, energy consumption, and economic growth in Jiangsu Province, China. *Emerging Markets Finance and Trade* 51(2): 391–399. doi: 10.1080/1540496X.2015.1016840

Jamil MN (2022). Critical analysis of energy consumption and its impact on countries economic growth: An empirical analysis base on countries income level. *Journal of Environmental Science and Economics* 1(2): 1–12. doi: 10.56556/jescae.v1i2.11

Jamil MN, Rasheed A, Mukhtar Z (2022). Corporate social responsibility impact sustainable organizational growth (firm performance): An empirical analysis of Pakistan stock exchange-listed firms. *Journal of Environmental Science and Economics* 1(2): 25–29. doi: 10.56556/jescae.v1i2.16

Kasman A, Duman YS (2015). CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. *Economic Modelling* 44: 97–103. doi: 10.1016/j.econmod.2014.10.022

Khan H, Khan I, BiBi R (2022). The role of innovations and renewable energy consumption in reducing environmental degradation in OECD countries: An investigation for innovation Claudia curve. *Environmental Science and Pollution Research* 29: 43800–43813. doi: 10.1007/s11356-022-18912-w

Khan H, Liu W, Khan I (2022a). The role of institutional quality in FDI inflows and carbon emission reduction: Evidence from the global developing and belt road initiative countries. *Environmental Science and Pollution Research* 29: 30594–30621. doi: 10.1007/s11356-021-17958-6

Khan H, Liu W, Khan I (2022b). Examining the effect of information and communication technology, innovations, and renewable energy consumption on CO_2 emission: Evidence from BRICS countries. *Environmental Science and Pollution Research* 29: 47696–47712. doi: 10.1007/s11356-022-19283-y

Khan H, Liu W, Khan I (2022c). The role of financial development and institutional quality in environmental sustainability: Panel data evidence from the BRI countries. *Environmental Science and Pollution Research*. doi: 10.1007/s11356-022-21697-7

Khan H, Liu W, Khan I, Lei H (2022). The effect of income inequality and energy consumption on environmental degradation: The role of institutions and financial development in 180 world countries. *Environmental Science and Pollution Research* 29: 20632–20649. doi: 10.1007/s11356-021-17278-9

Khan I, Han L, Bibi R, Khan H (2022a). The role of technological innovations and renewable energy consumption in reducing environmental degradation: Evidence from the Belt and Road initiative countries. *Environmental Science and Pollution Research*. doi: 10.1007/s11356-022-21006-2

Khan I, Han L, Bibi R, Khan H (2022b). Linking natural resources, innovations, and environment in the Belt and Road initiative countries using dynamic panel techniques: The role of innovations and renewable energy consumption. *Environmental Science and Pollution Research* 29: 59666–59675. doi: 10.1007/s11356-022-20093-5

Khan SAR, Zhang Y, Anees M, et al. (2018). Green supply chain management, economic growth and environment: A GMM based evidence. *Journal of Cleaner Production* 185: 588–599. doi: 10.1016/j.jclepro.2018.02.226

Koçak E, Şarkgüneşi A (2017). The renewable energy and economic growth nexus in the black sea and Balkan countries. *Energy Policy* 100: 51–57. doi: 10.1016/j.enpol.2016.10.007

Le HP, Ozturk I (2020). The impacts of globalization, financial development, government expenditures, and institutional quality on CO_2 emissions in the presence of environmental Kuznets curve. *Environmental Science and Pollution Research* 27(18): 22680–22697. doi: 10.1007/s11356-020-08812-2

Lee S, Lee B (2014). The influence of urban form on GHG emissions in the US household sector. *Energy Policy* 68: 534–549. doi: 10.1016/j.enpol.2014.01.024

Li X (2018). Linking residential electricity consumption and outdoor climate in a tropical city. *Energy* 157: 734–743. doi: 10.1016/j.energy.2018.05.192

Liddle B (2010). Age-structure, urbanization, and climate change in developed countries: Revisiting STIRPAT for disaggregated population and consumption related environmental impacts. *Population and Environment* 31: 317–343. doi: 10.1007/s11111-010-0101-5

Lin B, Liu H (2020). CO_2 mitigation potential in China's building construction industry: A comparison of energy performance. *Building and Environment* 94: 239–251. doi: 10.1016/j.buildenv.2015.08.013

Liu W, Khan H, Khan I, Lei H (2022). The impact of information and communication technology, financial development, and energy consumption on carbon dioxide emission: Evidence from the Belt and Road countries. *Environmental Science and Pollution Research* 29: 27703–27718. doi: 10.1007/s11356-021-18448-5

Ma X, Wang C, Dong B, et al. (2019). Carbon emissions from energy consumption in China: Its measurement and driving factors. *Science of The Total Environment* 648(27): 1411–1420. doi: 10.1016/j.scitotenv.2018.08.183

Maraseni TN, Qu J, Zeng J (2015). A comparison of trends and magnitudes of household carbon emissions between China, Canada and UK. *Environmental Development* 15: 103–119. doi: 10.1016/j.envdev.2015.04.001

Miao L, Gu H, Zhang X, et al. (2019). Factors causing regional differences in China's residential CO_2 emissions—Evidence from provincial data. *Journal of Cleaner Production* 224: 852–863. doi: 10.1016/j.jclepro.2019.03.271

Mir KA, Purohit P, Mehmood S (2017). Sectoral assessment of greenhouse gas emissions in Pakistan. *Environmental Science and Pollution Research* 24: 27345–27355. doi: 10.1007/s11356-017-0354-y

Mishra S, Sharif A, Khuntia S (2019). Does oil prices impede Islamic stock indices? Fresh insights from wavelet-based quantile-on-quantile approach. *Resources Policy* 62: 292–304. doi: 10.1016/j.resourpol.2019.04.005

Nathaniel S, Khan SAR (2020). The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries. *Journal of Cleaner Production* 272: 1–9. doi: 10.1016/j.jclepro.2020.122709

Nathaniel SP, Adeleye N (2021). Environmental preservation amidst carbon emissions, energy consumption, and urbanization in selected African countries: Implication for sustainability. *Journal of Cleaner Production* 285: 125409. doi: 10.1016/j.jclepro.2020.125409

Ocal O, Aslan A (2013). Renewable energy consumption-economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews* 28: 494–499. doi: 10.1016/j.rser.2013.08.036

Pablo-Romero MDP, Sanchez-Braza A (2017). Residential energy environmental Kuznets curve in the EU-28. *Energy* 125: 44–54. doi: 10.1016/j.energy.2017.02.091

Panayotou T (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development. ILO Working Paper. International Labour Organization.

Poumanyvong P, Kaneko S (2010). Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. *Ecological Economics* 70: 434–444. doi: 10.1016/j.ecolecon.2010.09.029

Poumanyvong P, Kaneko S, Dhakal S (2012). Impacts of urbanization on national residential energy use and CO_2 emissions: Evidence from low-, middle- and high-income countries. *IDEC DP2 Series* 2(5): 1–35.

Raheem A, Samo S, Memon A, et al. (2016). Renewable energy deployment to combat energy crisis in Pakistan. *Energy, Sustainability and Society* 6: 1–13. doi: 10.1186/s13705-016-0082-z

Sarkodie SA, Strezov V (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Science of the Total Environment* 646: 862–871. doi: 10.1016/j. scitotenv.2018.07.365

Shahzad SJH, Kumar RR, Zakaria M, Hurr M (2017). Carbon emission, energy consumption, trade openness and financial development in Pakistan: A revisit. *Renewable and Sustainable Energy Reviews* 70: 185–192. doi: 10.1016/j.rser.2016.11.042

Shen L, Wu Y, Lou Y, et al. (2018). What drives the carbon emission in the Chinese cities?—A case of pilot low carbon city of Beijing. *Journal of Cleaner Production* 174: 343–354. doi: 10.1016/j.jclepro.2017.10.333

Sohag K, Begum RA, Abdullah SMS (2015). Dynamic impact of household consumption on its CO_2 emissions in Malaysia. *Environment, Development and Sustainability* 17: 1031–1043. doi: 10.1007/s10668-014-9588-8

Sorrell S (2009). Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy* 37(4): 1456–1469. doi: 10.1016/j.enpol.2008.12.003

Soytas U, Sari R (2009). Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecological Economics* 68(6): 1667–1675. doi: 10.1016/j.ecolecon.2007.06.014

Soytas U, Sari R, Ewing BT (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics* 62(3–4): 482–489. doi: 10.1016/j.ecolecon.2006.07.009

Sultan M, Wu J, Aleem F, Muhammad I (2018). Cost and energy analysis of a grid-tie solar system synchronized with utility and fossil fuel generation with major issues for the attenuation of solar power in Pakistan. *Solar Energy* 174: 967–975. doi: 10.1016/j.solener.2018.09.052

Sun C, Ouyang X, Cai H, et al. (2014). Household pathway selection of energy consumption during urbanization process in China. *Energy Conversion and Management* 84: 295–304. doi: 10.1016/j.enconman.2014.04.038

Tanveer A, Song H, Faheem M, et al. (2021). Unveiling the asymmetric impact of energy consumption on environmental mitigation in the manufacturing sector of Pakistan. *Environmental Science and Pollution Research* 28: 64586–64605. doi: 10.1007/s11356-021-14955-7

The World Bank (2019). Population, total. Available online: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed on 16 August 2023).

Toklu E (2013). Overview of potential and utilization of renewable energy sources in Turkey. *Renewable Energy* 50: 456–463. doi: 10.1016/j.renene.2012.06.035

Ullah A, Khan D, Khan I, et al. (2018). Does agricultural ecosystem cause environmental pollution in Pakistan? Promise and menace. *Environmental Science and Pollution Research* 25: 13938–13955. doi: 10.1007/s11356-018-1530-4

Usman A, Ullah S, Ozturk I, et al. (2020). Analysis of asymmetries in the nexus among Pakistan's clean energy and environmental quality. *Environmental Science and Pollution Research* 27: 20736–20747. doi: 10.1007/s11356-020-08372-5

Wang Y, Zhao T (2015). Impacts of energy-related CO_2 emissions: Evidence from under developed, developing and highly developed regions in China. *Ecological Indicators* 50: 186–195. doi: 10.1016/j.ecolind.2014.11.010

Wen F, Ye Z, Yang H, Li K (2018). Exploring the rebound effect from the perspective of household: An analysis of China's provincial level. *Energy Economics* 7(5): 345–356. doi: 10.1016/j.eneco.2018.08.018

Yousaf M, Lin B (2020). Decoupling and mitigation potential analysis of CO_2 emissions from Pakistan's transport sector. *Science of the Total Environment* 730: 139000. doi: 10.1016/j.scitotenv.2020.139000

Yuan B, Ren S, Chen X (2015). The effects of urbanization, consumption ratio and consumption structure on residential indirect CO_2 emissions in China: A regional comparative analysis. *Applied Energy* 140: 94–106. doi: 10.1016/j.apenergy.2014.11.047

Zakaria M, Bibi S (2019). Financial development and environment in South Asia: The role of institutional quality. *Environmental Science and Pollution Research* 26(8): 7926–7937. doi: 10.1007/s11356-019-04284-1

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. doi: 10.1016/j.enpol.2017.03.072

Zubair AO, Samad ARA, Dankumo AM (2020). Does gross domestic income, trade integration, FDI inflows, GDP, and capital reduces CO_2 emissions? An empirical evidence from Nigeria. *Current Research in Environmental Sustainability* 2: 100009. doi: 10.1016/j.crsust.2020.100009