THE PROGRESS: A Journal of Multidisciplinary Studies
Vol.6, No.4 (December, 2025), Pp.115-131
ISSN (Online): 2958-292X, ISSN (Print): 2958-2911
DOI: https://doi.org/10.71016/tp/8kvrdc67

Original Article https://hnpublisher.com

Drivers of Carbon Emissions in a Developing Economy: The Role of Urbanization and Financial Development in Pakistan

Hira Shoaib[1], Abida Yousaf[2], Hajra Ihsan[3]

[1]Student, Department of Economics, International Islamic University, Islamabad, Pakistan.
[2]Lecturer, Department of Economics, International Islamic University, Islamabad, Pakistan.
[3]Assistant Professor, Department of Economics, International Islamic University, Islamabad, Pakistan.
Correspondence: hajra.ihsan@iiu.edu.pk[3]

ABSTRACT

Aim of the Study: This study investigates the links among urbanization, financial development, and carbon emissions in Pakistan over the time span of 1990 and 2020.

Methodology: The short-term and long-term associations between the variables are analysed by using the Autoregressive Distributed Lag (ADRL) bounds testing method.

Findings: The long-run estimates show that per capita GDP positively impacts carbon emissions, thereby indicating that economic growth in Pakistan over the period under study has continued to worsen the impact on climate change. At the same time, the square of the per capita GDP is statistically significant and positive which implies that the Environmental Kuznets Curve (EKC) hypothesis does not hold in the case of Pakistan. The estimates of financial development show a positive effect on CO2 emissions. In contrast, the area of forests and the use of renewable energy have significant and negative relation to carbon emissions indicating their positive role in the reduction of emissions. Urbanization, by contrast, has a significant positive relationship with emissions indicating the direct impacts of extensive urbanization on the environment.

Conclusion: The study concluded that financial development (FD) promotes carbon emissions in the short run while supporting emissions reduction in the long run is indicative of structural change and technology improvements. As a whole, the study is essential and provides Pakistan with the best policy opportunities where the country's economically sustainable development goals need to be aligned with the promotion of the environmentally sustainable goals of the country's financial system, adoption of renewable energy, afforestation, and eco-friendly urban development.

Keywords: Environment, Urbanization, Economic Growth, Foreign Direct Investment, Carbon Emissions.

Article History

Received:
September 17, 2025

Revised:
November 23, 2025

Accepted:
November 27, 2025

Online:
December 02, 2025

1. INTRODUCTION

Environmental degradation and economic costs linked to carbon emissions (CO2) are the prevailing issues in the contemporary world economies. Zhang et al. (2025), Wu et al. (2025), and Al Amosh and Khatib (2025) highlight the growing concern about the effect of carbon emissions (CO2) regarding the environment. The EKC was a primary tool in researching the associations between Economic Growth (EG) and CO2 (Khalid et al., 2025; Peng et al., 2025; Kong & Khan., 2019; Wang et al., 2024; Sun et al., 2021). This theory suggests that EG results in ecological worsening during the initial stages of growth trajectory, followed by environmental recovery after a country's per capita income hits a specific threshold (Jalil and Feridun, 2011). The EKC hypothesis gained significant attention in the energy literature after Zhang and Cheng (2009) incorporated energy use into the standard EKC framework.

One highly regarded theoretical paradigm that incorporates nonlinearities between EG and degradation of the environment is the EKC (Mahmood et al., 2023, Leal & Marques., 2022, Saliminezhad et al., 2022). The EKC theorizes that a country's ecological condition may be negatively affected by the early stages of economic development, however during the later stages of development, the overall environmental conditions improve with further development (Adejumo, 2020; Mahmood et al., 2023; Bibi & Jamil, 2021). This is represented as an inverted U-shaped curve indicating positive influences of growing technological change, EG, and social and political changes. The antagonistic reliance on weak energy resources impacts the health of all living things and the well-being of the planet through climate change and global warming, as stated by Zhang et al., 2018 and Alzard et al., 2019. Further, the UN's IPCC (2022) report stated 1.5°C rise in worldwide temperature which is alarming and demands immediate action to reduce the CO2 emissions of the 2 or 3 countries, primarily responsible for this climate change. As stated by the emission vehicles EDGAR report of 2018, the countries leading the world's CO2 emissions are the USA, India, China, Japan, Germany, Russia, South Korea, Iran, Indonesia and Saudi Arabia, and together these countries represent 67.6% of the world's CO2 emissions.

Increasing urbanization and industrialization have intensified the impact of urbanization on greenhouse gas emissions. Urbanization (URB) generates large population and lager economic activities, thus, increasing CO2 emissions (Pata, 2018; Chowdhury et al.,2019a; Chowdhury et al., 2019b). When the inhabitants of small towns move to cities, their energy use (including electricity and gas) increases, which raises the emission of carbon dioxide (Cho et al., 2014; Sohag et al., 2017). However, urbanization is a global phenomenon, with above fifty percent of the population living in 'urban' areas. Developing countries like Pakistan are experiencing high levels of urbanization, just as the developed countries are [Sadorsky (2014)]. In the case of Pakistan, continuous 'urban' population growth has resulted in the spreading and growth of larger cities. During the first five decades of its history, this 'urban' growth has caused significant and harmful impacts to the environment and to the socio-economic domains of governance, security, education, power and sanitation. The Government of Pakistan (2017) has pointed out that the percentage of 'urban' population in Pakistan has increased tremendously from 17.6 percent in 1951 to more than 40 percent today. Three main factors contribute to the rise of the 'urban' population: net 'rural-to-urban' migration, the conversion of formerly 'rural' regions into 'urban' centers, and natural population growth within urban families.

Surrounding rural areas gradually transform into 'urban' areas due to the overflow of urban activities, resulting in increased population density through natural growth and migration to peri-urban regions. Pakistan had the highest average annual 'urban' population growth rate in South Asia between 1990 and 2005, at 3.4 percent [Awan & Iqbal (2015)]. Pakistan is facing environmental issues as a result of the fast rate of urbanization.

The migration of people to cities is primarily driven by the availability of greater employment opportunities. The results from URB suggests that the increase in the "urban population" causes the growth in number of vehicles which affects the climate negatively. People migrate to cities from rural areas due to the higher expected wages, better healthcare, and education. This tends to put more pressure on the already limited resources available. Legislation of the changing population dynamics is impossible, particularly since people relocate to the areas that meet their personal preferences. By the year 2050, developing countries are anticipated to achieve almost 65% urbanization [Shahbaz et al. (2016)]. The highest possible urbanization is expected in the regions of Asia and Africa. Urbanization in these continents is expected to double from the year 2000 to the year 2030. The unemployed from rural regions usually migrate to cities in order to work, which increases the pressure on the cities' infrastructures. Urban hotspots leave people to handle the worst consequences of global warming due to the 'urban' heat island effect [Baksh et al. (2018)].

The effect of FD on environment occurs in two important ways. At one hand, it promotes the energy efficiency of imaginative technologies and also helps finance the enforcement of the regulations set out on the environment. It helps in providing funding which helps in lowering the costs of enforcing regulations on the environment [Tamazian et al. (2009)]. This technique aims to counteract the adverse effects on environmental pollution caused by FD. On the other hand, the low costs, high investments, and high energy usage caused by FD are likely to ignite economic growth [Dasgupta et al. (2001)]. This EG, in turn, has the potential to cause environmental damage.

FD has the potential to cause more environmental pollution by raising carbon emissions. To begin with, through the process of financial intermediation, consumers receive easy credit and hence gain access to various household and automotive CO_2 emitting technologies such as refrigerators, air conditioners, and vehicles [Zhang (2011)]. Also, the expansion of financial credit in the FD system allows people to spend more and invest in more projects with lower transaction costs, which leads to direct increases in CO_2 [Sehrawat and Mohapatra (2015)].

Urbanization and financial development are two processes that have been the core to economic development in developing countries, thus, are a great constraint towards environmental sustainability. The problem is acutely in line with the aims of the Sustainable Development Goals (SDGs), in particular, SDG 11 (Sustainable Cities and Communities), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action). In the case of Pakistan where rapid urbanization and financial sector growth are occurring, it is important to comprehend the interaction between the two so that consistent policy can be made. The paper is an empirical study of the nexus between URB, FD and carbon emissions (CO_2) in Pakistan between 1990 and 2020. The study will equip the powerful evidence to facilitate the strategies that would facilitate the reconciliation of the economic goals of the country with its environmental obligations and concerns towards the global agenda of sustainable development.

The critical nexus of urbanization, economic development, and CO_2 emission in Pakistan has been generally ignored in the previous literature. To fill the gap in the literature, this research offers empirical analysis these variables interaction through the investigation of the dynamics of URB, FD, and environmental degradation in Pakistan during 1990-2020. In order to devise appropriate environmental policies and regulations, it is important to understand the relationship between URB, FD, and carbon emissions in Pakistan. This paper will discuss these associations and will present policy options that can be used to rectify the adverse environmental effects of the high rate of growth of the urban sector and the financial industry.

This work makes some of the crucial contributions to the subject of sustainable development. It provides essential, region-specific evidence that relates to Pakistan, a climate-prone country whose dynamics are usually hidden from global comparative cross-country studies. Given that the research relies on 30 years of national information, the findings are presented with a certain degree of subtlety that can be directly implemented by the Pakistani policymakers without relying on the theoretical generalizations provided but on the basis of the ground-level reality.

The paper also contributes to the literature by taking an integrated approach by concurrently analyzing complex associations among urban growth, financial growth, and carbon footprint-drivers of SDG 11, 8, and 13. This comprehensive methodology highlights an important and challenging discovery: the association amid ecological worsening and economic development is not a self-correcting factor in Pakistan. The fact that the positive coefficient of squared GDP per capita strongly opposes the Environmental Kuznets Curve and serves as an evidence that emissions increase at a pace of the growth, and will not decrease on their own.

Besides, the analysis differentiates between the short run and long run effects. One of the most interesting discoveries is the dual nature of the financial development, that is, at the short term basis, it increases the emissions, but, in the long term, it has the potential of immediate reduction, as it is a complex process in which the current investments in the financial sector can be planted to grow and be converted to green in the future. The empirical findings of the study also confirms the hypothesis of the pollution haven, that there exists a positive relationship of foreign direct investment and increased emissions, which is a critical fact to be considered in the industrial policy.

Lastly, the study exhibits an effective mechanism that quantifies the tools that can be used to improve the situation. It shows that a 1 percent growth in the use of renewable energy sources will reduce the emission by 1.41 percent and a 1 percent increase in the size of forests will decrease the emission by 1.78 percent. They are not abstract but quantifiable tools and make a strong evidence-based argument to consider clean energy and conservation of forests as a key factor in the development agenda of Pakistan.

The paper is structured in the following manner: Section 2 is a literature review on the topic. Section 3 includes the theoretical framework and empirical model. The construction of data set and variables is presented in section 4. The empirical results are discussed and presented in section 5. Lastly, Section 6 is the conclusion of the study covering the findings and policy implications of the same.

2. LITERATURE REVIEW

The relation between CO2, output and the renewable energy (RE), urbanization, income, agriculture, and FD has been the focus of many studies [Chien et al. (2021); Balcilar et al. (2018); Sinha (2019); Jun et al. (2021)]. Some of these variables are positively correlated, while others are negatively correlated. These discrepancies arise from the use of different datasets, methodologies, countries, and time periods. [Adewuyi & Awodumi (2017); Anwar et al. (2021a); Sinha et al. (2019)]. Waheed et al. (2018) show that in Pakistan, from 1990 to 2014, the use of RE negatively impacts CO2, while the negative impact of agricultural activities on emissions is positively correlating emissions.

2.1 Financial Development and Carbon Emissions

Artur et al. (2009) explored the link between the environment, growth and FD in the BRIC using panel data from 1992 to 2004. They used some econometric approaches such as fixed-effects regression models. They argued that both finance and EG do help in reducing the environmental degradation and that the former is positively correlated with a reduction in global warming and CO2 emissions. By employing the ARDL bounds testing approach to cointegration, Nurul and Syed (2012) analyzed the long and short-run relationship of energy use, URB, EG, trade openness, FD, and CO2 emissions in Bangladesh from 1975 to 2010. The urbanization and increased energy use augmented CO2 emissions while CO2 emissions declined declines with a rise in GDP per capita. Their findings confirmed that the level of EG has a connection with a level of environmental degradation.

Mohammad et al. (2015) examined the connections between FD, EG, energy consumption, and CO2 emissions in the Gulf Cooperation Council (GCC) nations between 1980 and 2012. To investigate long-term associations for the variables, the authors employed estimation methodologies of FMOLS (fully modified least squares), DOLS (dynamic ordinary least squares), DFE (dynamic fixed-effect) on the panel data. The economy's CO2 emissions increased over time, and emissions FD had a detrimental impact on climate change, according to the results. The Granger causality test revealed that CO2 emissions and EG were causally related in both directions.

By utilizing ARDL limits test for cointegration, Shahzada et al. (2017) investigated the relationship among energy consumption (EC), openness (financial and commercial) and CO2 emissions for Pakistan over the period 1971 and 2011. The results of their study indicated a nonlinear association between carbon emissions and EC in the form of an inverted U type relationship. Further, FD and trade openness also affected CO2 emissions in unsustainable way. The results of Granger causality were one-way from FD to CO2 emissions. Mingyuan et al., (2019) considered sub panels of their overall panel data generated in accordance with different levels of FD using the time span of 1997 to 2015. They analysed the relationship of financial development (FD) with CO2 emissions employing an extended STIRPAT model. Their findings highlighted that that stock trading volume and FD efficiency led to higher emissions for the sub panels while the market value and FD were associated with lower emissions. Emissions impacts were different and varied by the different levels of FD.

The link of CO2 intensity in China and FDI was examined by Hongyan and Yanrong (2020) for the time span 2007 to 2016. They used a Spatial Durbin model for their CO2 spatial distributions across provinces. The findings of their study showed that while FD raises CO2 locally, it lowers CO2 in the surrounding areas, resulting in a net decrease in carbon emissions. Advanced econometric techniques of cointegration, structural breaks in the time series, stationarity, and the Autoregressive Distributed Lag (ARDL) framework were employed by Muzamil et al., (2022) to investigate the ecological footprint, the relationship between CO2 emissions and some other variables like consumer price and FD in China. Their study pointed out the existence of a U-shaped environmental Kuznets curve, indicating the mitigation of some environmental degradation ligated by economy’s development. Furthermore, Muzamil et al. (2022) demonstrated that although other factors like "population density" and "natural resource rents" had a negative impact on the decreases in CO2 emissions, FD had a favorable effect.

Liu and Chen (2022) utilized panel data of China to examine the effect of environmental regulation on green transformation and productivity of maritime industry of China. Their sample comprised the period from 2006 to 2016. Their econometric analysis highlighted the existence of regional variation and endogeneity in their analysis indicating a positive effect on maritime productivity, especially in the southern and eastern parts. Shahbaz et al. (2022) covered thirty regions of China to analyse the relationship between financial Inclusion (FI) and carbon emissions for the time period between 2011 and 2017 on the basis of the panel data. They used econometric methods to examine the spatial inequality in financial inclusion and its effects. The outcomes of the Granger causality tests indicated that financial inclusion made a significant contribution to air and CO2 emissions albeit with some regions having higher levels of such impact. Their study pointed out that FI have indirect effect of decreasing the CO2 emissions due to the expansion of green energy infrastructure and consumption.

This review show cases the different econometric techniques utilized in the assessment of the interactions between FD, environmental quality, and energy consumption, including ARDL bounds testing, FMOLS, DOLS, fixed-effects regression models, and Spatial Durbin models. The outcomes demonstrate that FD has a vital role in mitigating the adverse environmental impacts, though the effects are conditional upon energy consumption, URB, and spatial heterogeneity.

2.2 Urbanization and Carbon Emissions

Zhang and Lin (2012) used the STIRPAT model to investigate the geographical impact of URB and Energy Consumption (EC) on carbon emissions in China between 1995 and 2010. They demonstrated that, despite notable regional variations, particularly between the east and the west, URB stimulates EC and CO2 emissions. Saidi and Mbarek (2017) examined how trade openness, FD, URB, and income affected CO2 emissions for a group of developing nations between 1990 and 2013. The results defy the EKC hypothesis by demonstrating that whereas FD had a long-term detrimental impact on emissions, URB helped to reduce CO2 emissions. Chun and Xiaxin used GMM in 2019 to examine the connection between 155 nations' FD and CO2 emissions. While there were no statistically significant findings for developed countries, there was a general increase in CO_2 emissions as a result of FD. Gulam et al., (2020) analysed the CO_2 emissions in the world's ten largest emitter countries with sustainable development considering the causal relationship among URB, FD, globalization and renewable energy. Using data from 1990 to 2016 for nations including the USA, China, India, and Russia they applied advanced panel data techniques. Their findings revealed that FD and URB significantly increased emissions over the long term, while renewable EC effectively reduced them. Further, their analysis also exposes specific causal relationship, such as emissions driving FD, rather than the other way around. Renewable EC appeared as a critical lever for these countries to achieve sustainable development.

Tomiwa et al. (2021) tested the association among FD, URB, Economic Growth (EG), and EC on the CO_2 emission of Latin America during the period 1980 to 2017 using FMOLS, DOLS and Westerlund cointegration test. They concluded that URB, EG and EC were antecedents of the rise of CO_2 emissions and that EC and EG were prognosticative of the emissions. The results relating FD were complex showing mixed impacts based on the economic development and region.

A number of studies have shown that Urbanization (URB) raises levels of environmental degradation and pollution (Xie et al., 2020; Al-Mulali et al., 2012; Yu et al., 2020). Contrarily some studies like Ali et al (2017) pointed out that URB has the potential to improve environmental issues. Likewise, literature on the association of FD and CO_2 emissions also remained inconclusive. Some researchers claim FD as a contributing factor to the reduction of carbon emissions (Shahbaz et al., 2018) while others identify FD as a factor that increases environmental pollution and carbon emissions (Shahzad et al., 2017).

While looking at all the research that's been discussed above, it's clear that the connections between financial growth, urban expansion, and carbon emissions have been studied in many parts of the world. But the results are all over the map—what holds true in one country might not in another, depending on its economy and stage of development. While this global picture is helpful, there's a specific blind spot when it comes to Pakistan. Despite the country's rapid urban spread and growing financial sector, which bring serious environmental pressures, there hasn't been a thorough, up-to-date study that puts all these pieces together for the Pakistani context. This is where our study steps in. This study is focusing specifically on Pakistan, using data from 1990 to 2020 to untangle how urbanization and financial development have influenced carbon emissions over time. By providing these insights, we hope to offer practical, evidence-based guidance to help Pakistan pursue its economic ambitions without sacrificing its environmental health.

3. THEORETICAL FRAMEWORK

To position the research question, this section describes the conceptual underpinnings that inform the study and derives from a few established models and general approaches within the literature.

3.1 The Environmental Kuznets Curve (EKC)

The EKC hypothesis, building on Kuznet's original work Kuznets (1955), asserts that environmental decline is correlated in an inverted U pattern. In 1955, Kuznets put forth the Kuznets curve, which demonstrated that income inequality and income per capita were inversely correlated in a U shaped pattern. EKC, or environmental Kuznet's curve, emerged in 1990 when the focus of economists shifted to environmental issues. This can be largely attributed to Shafik and Bandyopadhyay in 1992, and Grossman, and Krueger in 1991. According to the EKC hypothesis, there is a U-shaped relationship between per capita income and specific environmental conditions.

There is a worsening of environmental conditions due to an increase in pollution emissions during the early stages of EG. On the other hand, the pattern changes once a particular amount of income per capita is attained (which varies depending on the indicator). EG helps to improve the environment at higher income levels. Stated differently, there is an inverted U-shaped pattern in the link between per capita income and environmental consequences or emissions. Economists have widely adopted the EKC to model aggregate emissions and ambient pollution concentrations since its introduction by Grossman and Krueger in 1991. While the EKC is primarily an observed phenomenon, many estimates of Environmental Kuznet Curve models lack statistical robustness. Although the levels of specific local pollutants have reduced in developed nations, there has been a rise in the emissions of several other pollutants (Grossman, & Krueger, 1991).

Poorer nations are often associated with cleaner environments due to lower utilization levels and a lack of industrialization. Initially, the primary focus is on agriculture. In any case, every economy will move on to industrialization, which will then cause pollution. The focus of the country will eventually change as the economy progresses. They will begin to adopt cleaner technologies, spending their money on providing less dirty air and water, rather than just keeping their focus on the output. The adverse effects of pollution will begin to reverse and slow down. Moving on to the next stage of EG the economy will focus on providing services which will improve the environment even more. Here, there is a missing piece, which is the goal of the firms to socially set and improve their boundaries on the environment. Distinguishing cleanliness of the agriculture and the dirtiness of industry, the country will move to cleaner agriculture, then dirtier industry, and then move to provide cleaner industry and services for the country. To put it plainly, the dirtier the country is, the cleaner the agriculture will be. This is well documented as the pollution haven phenomenon. This phenomenon states that the business will move their production to a country that is less developed that has flexible pollution control.

Some look at the EKC theory and think that exclusive focus on raising income at the expense of the environment is a risky proposition. The EKC theory states that, at least, theoretically, and at the early phases of URB and development, environmental issues grow. And it states that the higher the level of economic development, there comes a point where environmental issues shrink. This is, in part, guided, or determined, by the socio-political landscape with the imposition of Environmental regulations, technological innovation, and a shift to low-and-non carbon energy. The EKC theory is not of urbanization and development. The conclusion is that throughout the initial phases of development and urbanization, there is a cost or rise, while at mature stages, the socio-political landscape shifts in equilibrium and permits and fosters environment shrinking.

3.2 The Financial Development and Clean Energy Transition Theory

The FD and Clean Energy Transition Theory examine the way forward with financial development and the transition to a cleaner energy system. Given the vital role that sustainable finance, responsible investment, and the financing continuum for a strong financial system plays in promoting sustainable energy and addressing decarbonization, this theory posits the impact of financially clean shifts in the economy. Shifting the financing for financial system and economic activities that are clean and sustainable would, in turn, create a positive impact and develop financial systems. According to the theory, the various ways FD enables a clean energy transition are the provision of funds required for the entire spectrum of clean energy from renewables to energy-efficient infrastructure, and the financing of technological development, risk management, and uncertainty mitigation within the regulatory environment. Financial innovations, e.g. green bonds and climate funds, mobilize the impact of investing and FD for clean system shifts and climate financing. Lastly, the innovation and commercialization of new sustainable technologies, and the scaling of sustainable solutions develop financed policies. Well-functioning financial systems unlock the potential for market instruments such as carbon markets and RE certificates to render clean energy profitably viable and appealing (Arminen & Kuosmanen, 2019).

4. METHODOLOGY

4.1 Empirical Model

This endeavour seeks to examine the nexus involving URB, FD, and carbon emissions. The underlying reason for this inquiry is to investigate the potential claim that economic efficiency is augmented by FD

[(Sadorsky, 2011)]. To estimate the connection among URB, FD, and carbon emissions, we have adopted the model based on the study of Ahmad et al. (2019). Below is an explanation of the model's general functional form:

$$CO_2=f\,(URB, FD, GDP, GDP^2, RE, FA, FDI) \qquad (1)$$

Where CO_2 means Carbon Dioxide emission, URB is the urbanization, FD is the financial development, RE is the Renewable Energy Consumption , FA is the forest area. FDI is the foreign direct investment, GDP is GDP per capita and GDP^2 is the square of GDP per capita. The empirical model is:

$$CO_{2t} = \alpha_0 + \alpha_1(URB)_t + \alpha_2(FD)_t + \alpha_3(RE)_t + \alpha_4(GDP)_t + \alpha_5\,(GDP)_t^2 + \alpha_6(FA)_t + \alpha_7(FDI)_t + \epsilon_t \qquad (2)$$

In this model, CO2 represents carbon emissions quantified in metric tonnes per capita, FDt denotes the ratio of domestic credit to the private sector as a percentage of GDP, URB indicates the proportion of the ‘urban’ population relative to the total population, RE signifies the percentage of total EC, FA refers to the forest area measured in square kilometres, GDP represents GDP per capita in US dollars, GDP2 is the square of GDP per capita, and FDI indicates net FDI as a percentage of GDP (BOP, Current US dollars). The term εt is presumed to be a white noise error term, and t denotes time.

4.2 Estimation Technique

The empirical analysis is based on ARDL to estimate the effect of URB along with FD on carbon emissions.

4.3 ARDL Bound Testing Approach

The ‘ARDL bounds’ approach is a cointegration technique introduced by Pesaran et al. (2001) to explore whether there is a long term association among variables. Economic theory posits that the effect of one economic variable on another takes time and is not instantaneous. We employed the ARDL bounds test because it takes integration techniques rather than one-off techniques. Integrating the same techniques provides flexibility. Unlike the other bounds tests, ARDL bounds tests perform well with small samples. It provides estimates that are not conservative on the long-run. Finally, ARDL bounds tests can be carried out on inter-temporal sequences integrated of order I(0) and I(1). This increases the possibilities the model can approach. All tests confirmed bounds testing techniques provides flexibility, better estimates, and precise long-run estimates making a good model for cointegration.

The ARDL model of the study can be represented as follow

$$\Delta CO_{2,t} = \beta_o + \beta_1\sum_{i=1}^{\rho}\Delta URB_{t-1} + \beta_2\sum_{i=1}^{\rho}\Delta FD_{t-1} + \beta_3\sum_{i=1}^{\rho}\Delta RE_{t-1} + \beta_4\sum_{i=1}^{\rho}\Delta GDPPC_{t-1} + \beta_5\sum_{i=1}^{\rho}\Delta GDPPC_{t-1}^2$$
$$+ \beta_6\sum_{i=1}^{\rho}\Delta FA_{t-1} + \beta_7\sum_{i=1}^{\rho}\Delta FDI_{t-1} + \gamma_1 URB_{t-1} + \gamma_2 FD_{t-1} + \gamma_3 RE_{t-1} + \gamma_4 GDPPC_{t-1} + \gamma_5 GDPPC_{t-1}^2 + \gamma_6 FA_{t-1}$$
$$+ \gamma_7 FDI_{t-1} + \varepsilon_t$$

Where β_0 show constant, ε_t is the white noise disturbance term, and the error correction dynamics is denoted by the summation sign. Akaike's Information Criterion (AIC) will be used for the selection of appropriate lag length and then the Bound test will be used to check the presence of co-integration among the variables of the study. If the long run relationship exists among the variables of the study and carbon emission then the following model will be employed to estimate the long run estimates of the model by using the following model

$$CO_{2,t} = \alpha_o + \alpha_1 \sum_{i=1}^{\rho} \Delta URB_{t-1} + \alpha_2 \sum_{i=1}^{\rho} \Delta FD_{t-1} + \alpha_3 \sum_{i=1}^{\rho} \Delta RE_{t-1} + \alpha_4 \sum_{i=1}^{\rho} \Delta GDPPC_{t-1} + \alpha_5 \sum_{i=1}^{\rho} \Delta GDPPC_{t-1}^2$$
$$+ \alpha_6 \sum_{i=1}^{\rho} \Delta FA_{t-1} + \alpha_7 \sum_{i=1}^{\rho} \Delta FDI_{t-1} + \mu_t$$

In next step, we estimate the short run estimates by using the following model

$$\Delta CO_{2,t} = \eta_o + \eta_1 \sum_{i=1}^{\rho} \Delta URB_{t-1} + \eta_2 \sum_{i=1}^{\rho} \Delta FD_{t-1} + \eta_3 \sum_{i=1}^{\rho} \Delta RE_{t-1} + \eta_4 \sum_{i=1}^{\rho} \Delta GDPPC_{t-1} + \eta_5 \sum_{i=1}^{\rho} \Delta GDPPC_{t-1}^2$$
$$+ \eta_6 \sum_{i=1}^{\rho} \Delta FA_{t-1} + \eta_7 \sum_{i=1}^{\rho} \Delta FDI_{t-1} + \lambda ECT_{t-1} + \varepsilon_t$$

4.4 Data and Data Sources

Data from the World Bank's "World Development Indicators (WDI)" database covering the years 1990 to 2020 were used to investigate the relationship between FD, URB, and carbon emissions in Pakistan. The appendix contains tables A1 and A2 for variable construction.

5. RESULTS AND DISCUSSION

5.1 Unit Root Test

The use of a unit root test is vital to prevent erroneous regression. By considering differences and applying stationary processes to obtain the equation of interest, it assesses if the variables in a regression model are stationary. When a time series is stationary, it signifies that the effects of shocks on the series are transient, and the series tends to revert to its long-run mean values over time. Conversely, a non-stationary time series has a permanent component and does not have a long-run mean to which it converges. The unit root test was used to make sure that no variable went beyond the order of integration. Table 1 indicates that CO2, FD, GDP per capita square, and REC are non-stationary at the level but achieve stationarity at their first difference. Furthermore, the forest area, FDI, and GDP per capita are stationary at level, while the ‘urban’ population is non-stationary but achieves stationarity at the first difference.

Table 1: *Dicky-Fuller-GLS Unit Root Test (1990-2020)*

Variable	Level	First Difference	1%	5%	10%	Order of Integration
CO_2	-1.0916	-4.2983	3.6793	2.9677	2.6229	I(I)
LFD	-0.6176	-4.22788	3.6793	2.9677	2.6229	I(I)
LFA	-4.8759	--	3.6793	2.9677	2.6229	I(0)
LGDPPC	-0.7877	-4.4218	3.6793	2.9677	2.6229	I(0)
$LGDPPC^2$	-0.6770	-4.1748	3.6793	2.9677	2.6229	I(I)
LRE	-1.6230	-4.7554	3.6793	-2.977	2.6229	I(I)
LUP	1.57188	-1.9733	3.6793	-2.979	2.6229	I(I)
FDI	-2.9112	--	3.6793	2.9677	2.6229	I(0)

5.2 Results of ARDL Bound Test

It is essential to conduct a bound test to determine whether there is a long-term link between the study's explanatory factors and carbon dioxide emissions (CO2) before assessing both short-term and long-term impacts. After the stationarity of the series was confirmed, we evaluated cointegration using the ARDL bounds test. By selecting the configuration that produced the lowest "Akaike's Information Criterion (AIC)" value for F-statistic computation, this study determined the ideal lag length. To determine the cointegration connection between the variables, Table 2 presents the findings of the ARDL limits test. The following is how it is articulated. The estimated F-value exceeds both the upper and lower critical boundaries which confirms the variables have a (long-term) relationship. The critical upper and lower bounds were exceeded at the 10%, 5%, and 1% levels for both zero and first-order lags, thus the estimated F-statistic value of 17.847 confirms the null hypothesis can be rejected, thus reflecting a long run relationship among the variables.

Table 2: *F-Statistic Results*

Dependent Variable:CO_2						
	90%		**95%**		**99%**	
F-Statistics	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
17.847	1.92	2.89	2.17	3.21	2.73	3.9

5.3 Long and Short Run Estimates of the Model

Long-run results of the model demonstrate significant long-run relationships in the five variables of interest. As demonstrated in Table 3, GDP per capita is a significant determinant of carbon emissions, as evidenced by the coefficient estimate of 0.832 for GDPPC, corroborating results by [Jalil and Muhammad (2009)]. Jalil and Muhammad (2009) also documented the direct association of per capita GDP and CO2 emissions, thus linking it to ecological degradation. From a positive perspective, the results suggest that the pressure on the environment as a result of income growth and improvement is primarily due to EG stage of the country, as evidenced by the EG rate of Pakistan. Positive results linking pressure on the environment from EG suggest the country employs more resources than necessary to produce income, thus costing the environment more. Moreover, the results suggest a more than proportionally positive association between GDPPC2 (squared term of GDP per capita) and carbon emissions. This is indicative that as GDPPC increases, carbon emissions increase exponentially. This suggests that, in Pakistan, the EKU, which posits an inverted U-shaped association between income and environmental degradation, is not applicable.

The results for domestic credit indicate a statistically significant valuve of 0.107. Thus, it can be said that FD influences climate change negatively. A one percent increase in domestic credit is associated with 0.107 percent increase carbon emissions. That is, more FD, which is associated with more accessible capital, greater capital for investment, and technological advances contributes to EG and industrialization of a country. On the other hand, such growth is accompanied with greater energy use and the unregulated growth and pollution of industries. Thus, such growth is associated with increased carbon emissions. This supports the findings of [Zhang 2011].

Having observed a coefficient of 0.832 for GDPPC, it can be said that a 1% increase (or reduction) of GDPPC would mean a 0.832 unit increase (or decrease) on carbon emissions. This result also agrees with what Jalil and Muhammad (2009) who also found a positive linkage between GDP per capita and carbon emissions leading to possible environmental deterioration. The association between GDP per capita and carbon emissions suggests that relatively low per capita income countries—such as Pakistan—are burdening their economy with negative environmental impacts during the initial stages of their economic development. Pakistan displays positive and, indeed, statistically significant relationships with respect to carbon emissions and GDPPC2 (the squared term of GDP per capita) suggesting the rate of increase in carbon emissions is greater than the increase in GDP per capita. This suggests that the U-shaped environmental Kuznets curve, which is characterized as inversed, does not apply to Pakistan. With respect to domestic credit, which has an estimate of 0.107, shows that increase of domestic credit, within the context of this study, will increase CO2 emissions. The result suggests that increased credit facilities and financial systems' technological advances , and therefore increased economic and industrial growth, for which flow-oriented financial development (FD) provides the backbone, will also increase the burden of costs of emissions. This indicates that such advancement may lead to increased carbon emissions because of increased energy use and exposure to pollutant emissions as industries operate. This aligns with the findings of Zhang (2011).

The long-term coefficient estimates for forest area shows negative values which reflects that in the long run, an increase in forest area by one percent, CO2 emissions will decrease by 1.78 percent. Hence, forest degradation and deforestation, whereby a forest area gets reduced by one percent, will see an increase in CO2 emissions by 1.78 percent in Pakistan. Results show that enlarging forest area is beneficial to the environment since forests absorb CO2 and retain it in tree biomass. The long-run coefficient of renewable energy use is also negative, and statistically significant at a one percent level, which shows that an increase in the use of renewable energy by one percent will assist in emissions reduction by 1.41 percent. Hence, in Pakistan there is a significant opportunity to reduce emissions by expanding the use of renewable energy. On the other hand, an increase in the urban-rural balance (URB) has a positive long-run statistically significant result. This reflects a 1% increase in URB will increase CO2 emissions by 2.85 percent. This concretely shows that URB drives deforestation activities and contributes to the deprivation of the environment in Pakistan.

These findings correlate with the previous research of Asif et al. (2022), Zhang and Lin (2012), Ghulam et al. (2020), and Nurul and Syed (2010). Moreover, the relationship between FDI and carbon emissions is positive and statistically significant. This positive relationship between FDI and carbon emissions establishes regional support for the pollution haven hypothesis with respect to the data for Pakistan. A change of one percent increase in FDI is associated with a change of 0.023 percent increase in carbon emissions. This indicates that FDIs tend to contribute to higher carbon emissions in host countries, which is consistent with the findings of [Copeland and Taylor (1995), Suri and Chapman (1998) and Hettige, Mani and Wheeler (1998), Bakhsh (2017)].

Table 3: *Long Run Estimates of the Model*

Dependent Variable: CO_2		
Variable	**Coefficient**	**T-Statistic**
LNGDPPC	0.8324*** (0.234)	3.556
LNGDPPC2	0.0717*** (0.017)	4.231
LNFD	0.1077* (0.056)	1.917
LNFA	-1.7800** (1.028)	-1.729
LNRE	-1.4153*** (0.116)	-12.164
LNUP	2.8553** (1.238)	2.305
FDI	0.0237** (0.009)	2.488
C	39.0423** (15.296)	2.552

Note: t- stat values are given in the parenthesis.

The short-term model estimates show that every factor has a positive impact on carbon emissions and is statistically significant (see Table 4). This indicates that all of these factors have the impact of increasing carbon emissions to a degree that is statistically significant. Notably, compared to their long-run counterparts, the magnitude of the short-run coefficients is relatively smaller. LGDPPC, LGDPPC2, LFD, LFA, LRE, LUP, and FDI appear to be more environmentally harmful in the long run as compare to short run based on consistency between short-term and long-term estimates.

Table 4: *Short Run Estimates of the Model*

Dependent Variable: CO_2		
Variable	**Coefficient**	**T-Statistic**
LNGDPPC	0.8394** (0.39)	2.119
LNGDPPC2	0.0600** (0.03)	1.998
LNFD	-0.0900* (0.04)	-1.956
LNFA	-1.4894** (0.630)	-2.363
LNRE	-1.1842*** (0.16)	-7.071
LNUP	2.3891** (0.973)	2.455
FDI	0.0198*** (0.00)	3.158
ECM(-1)	-0.83 (0.05)	-14.89
C	32.668* (17.33)	1.884

Note: Stansards errors are enclosed in parenthesis. *, **,*** indicating significance at 10%, 5% and 1% respectively.

To analyze the impact short-term deviation from equilibrium, the Error Correction (EC) Model indicates the speed of adjustment to the long run equilibrium in the following periods. The value on the correction term in the model is significant and negative. This shows that from the previous year to the present, 0.83 percent of the long-run equilibrium deviation has been corrected. The value illustrates the responsiveness of the system and the system's ability to restore any long-term equilibrium from a disturbance or a short-term shock.

With respect to Foreign Direct Investment, we have ascertained that it could negatively impact short-run carbon emission estimations, while positively influencing long-run estimations. This is due to the characteristics of economic shifts and the temporal extent for impacts of FD to show. From the short-run perspective, when FD inflows are rapid, higher levels of economic activity and consumption take place, thereby potentially inflating carbon emissions as industrial production and energy use escalate. Contrariwise, in the long-run, FD accelerates long-term structural changes within the economy, which includes more efficient economic mechanisms, innovations, and the transition to less polluting and more sustainable alternatives. The extent to which these changes reduce the adverse impacts on the environment which are observed in the short-run, is significant. This is in agreement with the findings of former studies, such as [Xie, Lin, and Zhang (2020)], which have documented the same phenomena in other contexts.

5.4 Stability Tests

The Cumulative Sum (CUSUM) and CUSUM of Squares (CUSUMSQ) tests have been used to verify the model's stability. Additionally, stability tests to manage the long- and short-term limitations are performed using the CUSUM and CUSUMSQ check techniques (Brown et al., 1975). The stability test result graphs in Figures 1 and 2, which show the parameters' stability over the long and short periods from 1990 to 2020, show that both values are within the critical limits at a 5% significance level.

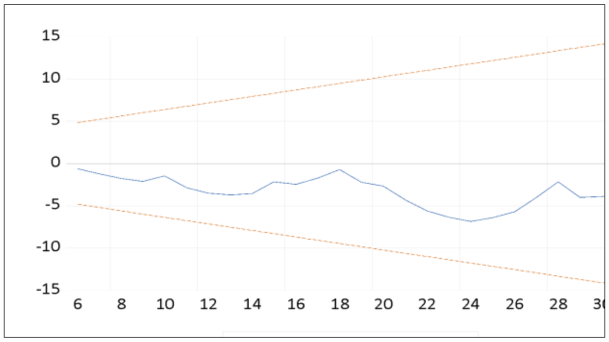

Figure 1: *Diagram of Cumulative Sum of Recursive Residuals*

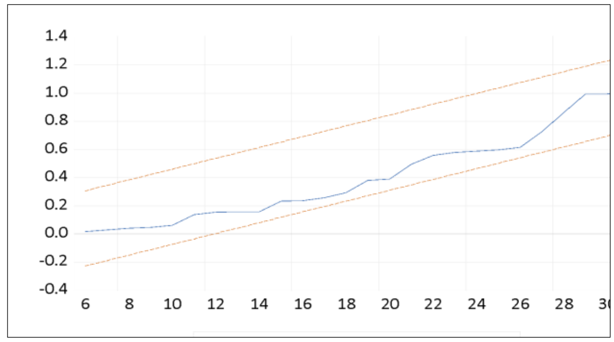

Figure 2: *Diagram of Cumulative Sum of Squares of Recursive Residuals*

6. CONCLUSION

This study aims to explore the intricate relationship among URB, FD along with CO_2. Using ARDL model the study reveals that the increase in per capita gross domestic product (GDPPC) shows that economic development as well as CO_2 are positively linked, suggesting a lack of sustainability practices. Similarly, FD manifets a positive relationship with CO_2 emissions, potentially due to investments in high-carbon industries and limited green financing options. URB is positively associated with CO_2, it shows that growing 'urban' areas consume even more energy while enhancing industrial expansion. Moreover, expanding forest areas and growing CO2 levels have a negative relationship, which means that deforestation causes a rise in emissions. Foreign Direct Investments also results in growing CO2 emissions, which may be attributed to investments in energy demanding industries and environmentally lax regulative policies relating FDI.

This research provides a crucial reality check for Pakistan's development path. By analyzing thirty years of data, it demonstrates that the country's economic and urban growth is directly increasing carbon emissions, disproving the optimistic theory that prosperity would eventually solve environmental problems on its own. The study offers a powerful, evidence-based argument that waiting for a turnaround is not an option; proactive and integrated policies are needed now.

Furthermore, the paper moves beyond simple diagnoses to quantify the real-world impact of potential solutions. It shows that investing in renewable energy and protecting forests are not just symbolic gestures they are powerful, measurable tools for cleaning the air. By revealing how foreign investment and financial credit can inadvertently fuel pollution, the study provides a clear-eyed guide for policymakers to steer the economy toward a healthier, more sustainable future for all Pakistanis. For the realization of positive impacts of urbanization there is need to adopt energy efficient structures, green public transport, and other eco positive 'urban' infrastructures need to be built.

Acknowledgments

None.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding Source

The authors received No funding to conduct this study.

ORCID's

Hira Shoaib [1] https://orcid.org/0009-0006-9348-7891
Abida Yousaf [2] https://orcid.org/0000-0002-6768-6030
Hajra Ihsan [3] https://orcid.org/0000-0002-2228-5890

REFERENCES

Adejumo, O. O. (2020). Environmental quality vs economic growth in a developing economy: complements or conflicts. *Environmental Science and Pollution Research*, *27*(6), 6163-6179. DOI: 10.1007/s11356-019-07101-x

Ahmad, N., Ali, S., & Khan, M. A. (2019). The impact of FD on environmental degradation in Pakistan. *Journal of Environmental Management, 250*, 109470. doi:10.1016/j.jenvman.2019.109470.

Al Amosh, H., & Khatib, S. F. (2025). Environmental innovation and carbon emissions reduction in European healthcare: the moderating role of environmental monitoring practices. *Cleaner and Responsible Consumption*, *16*, 100255. https://doi.org/10.1016/j.clrc.2025.100255

Ali, H. S., Abdul-Rahim, A. S., & Ribadu, M. B. (2017). Urbanization and carbon dioxide emissions in Singapore: evidence from the ARDL approach. *Environmental Science and Pollution Research*, *24*(2), 1967-1974. DOI: 10.1007/s11356-016-7935-z.

Al-Mulali, U., Sab, C. N. B. C., & Fereidouni, H. G. (2012). Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission. *Energy*, *46*(1), 156-167. DOI: 10.1016/j.energy.2012.08.043

Artur, L., & Hilhorst, D. (2012). Everyday realities of climate change adaptation in Mozambique. *Global Environmental Change*, *22*(2), 529-536. https://doi.org/10.1016/j.gloenvcha.2011.11.013

Awan, F. H., Dunnan, L., Jamil, K., & Gul, R. F. (2023). Stimulating environmental performance via green human resource management, green transformational leadership, and green innovation: a mediation-moderation model. *Environmental Science and Pollution Research*, *30*(2), 2958-2976. https://doi.org/10.1007/s11356-022-22424-y.

Bakhsh, K., Rose, S., Ali, M. F., Ahmad, N., & Shahbaz, M. (2017). Economic growth, CO_2 emissions, renewable waste and foreign direct investment relation in Pakistan: New evidences from 3SLS. *Journal of environmental management*, *196*, 627-632. https://doi.org/10.1016/j.jenvman.2017.03.029

Balcilar, M., Ozdemir, Z. A., Ozdemir, H., & Shahbaz, M. (2018). The renewable energy consumption and growth in the G-7 countries: Evidence from historical decomposition method. *Renewable Energy*, *126*, 594-604. https://doi.org/10.1016/j.renene.2018.03.066

Chien, F., Anwar, A., Hsu, C. C., Sharif, A., Razzaq, A., & Sinha, A. (2021). The role of information and communication technology in encountering environmental degradation: proposing an SDG framework for the BRICS countries. *Technology in Society*, *65*, 101587. https://doi.org/10.1016/j.techsoc.2021.101587

Cho, C. H., Chu, Y. P., & Yang, H. Y. (2014). An environment Kuznets Curve for GHG emissions: a panel cointegration analysis. *Energy Sources, Part B: Economics, Planning, and Policy*, *9*(2), 120-129. https://doi.org/10.1080/15567241003773192

Chowdhury, M. M. I., Rahman, S. M., Abubakar, I. R., Aina, Y. A., Hasan, M. A., & Khondaker, A. N. (2020). A review of policies and initiatives for climate change mitigation and environmental sustainability in Bangladesh. *Environment, Development & Sustainability*, *23*, 1133-1161. https://doi.org/10.1007/s10668-020-00627-y

Copeland, B. R., & Taylor, M. S. (1995). Trade and the environment: a partial synthesis. *American Journal of Agricultural Economics*, *77*(3), 765-771. https://doi.org/10.2307/1243249

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement. https://doi.org/10.3386/w3914

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The quarterly journal of economics*, *110*(2), 353-377. https://doi.org/10.2307/2118443

Huang, J., Wang, L., Wang, D., & Lei, H. (2020). Decreasing China's carbon intensity through research and development activities. *Environmental Research*, *190*, 109947. https://doi.org/10.1016/j.envres.2020.109947

Jalil, A., & Feridun, M. (2011). The impact of growth, energy and FD on the environment in China: a cointegration analysis. *Energy economics*, *33*(2), 284-291. https://doi.org/10.1016/j.eneco.2010.10.003

Khalid, W., Nawaz, A., Gadou, L. M. A., Khan, S. U., & Aybudak, H. G. (2025). Examining short-run and long-run nexus between economic growth, FD, energy consumption and environmental degradation: empirical evidence for the EKCHypothesis in Egypt. *Asia-Pacific Journal of Regional Science*, 1-33. https://doi.org/10.1007/s41685-025-00371-z

Kong, Y., & Khan, R. (2019). To examine environmental pollution by economic growth and their impact in an Environmental Kuznets Curve (EKC) among developed and developing countries. *PloS one*, *14*(3), e0209532. https://doi.org/10.1371/journal.pone.0209532

Leal, P. H., & Marques, A. C. (2022). The evolution of the EKC hypothesis assessment: A literature review under a critical analysis perspective. *Heliyon*, *8*(11). https://doi.org/10.1016/j.heliyon.2022.e11521

Liu, H., & Song, Y. (2020). FD and carbon emissions in China since the recent world financial crisis: Evidence from a spatial-temporal analysis and a spatial Durbin model. *Science of the Total Environment*, *715*, 136771.67. https://doi.org/10.1016/j.scitotenv.2020.136771

Liu, X., & Chen, S. (2022). Has environmental regulation facilitated the green transformation of the marine industry? .*Marine Policy*, *144*, 105238. https://doi.org/10.1016/j.marpol.2022.105238

Mahmood, H., Furqan, M., Hassan, M. S., & Rej, S. (2023). The Environmental Kuznets Curve (EKC) hypothesis in China: A review. *Sustainability*, *15*(7), 6110. https://doi.org/10.3390/su15076110

Mingyuan, W. A. N. G., Yingming, L. I., & Zitong, W. A. N. G. (2021). Green technological innovation and financial performance of enterprises in dual uncertainty of technology and market. *Journal of Systems & Management*, *30*(2), 353. DOI:10.3969/ji.ssn1005-2542.2021.02.014

Muhammad, N., Scrimgeour, F., Reddy, K., & Abidin, S. (2015). The impact of corporate environmental performance on market risk: The Australian industry case. *Journal of Business Ethics*, *132*(2), 347-362. https://doi.org/10.1007/s10551-014-2324-3

Muzammil, M., Zahid, A., & Breuer, L. (2021). Economic and environmental impact assessment of sustainable future irrigation practices in the Indus Basin of Pakistan. *Scientific reports*, *11*(1), 23466. https://doi.org/10.1038/s41598-021-02913-9

Nurul, S. (2023). Artificial Intelligence for Critical Power Infrastructure: Challenges and Opportunities. *Applied IT & Engineering*, *1*(1), 1-9. https://doi.org/10.25163/engineering.1110397

Pata, U. K. (2018). Renewable energy consumption, URB, FD, income and CO_2 emissions in Turkey: testing EKC hypothesis with structural breaks. *Journal of cleaner production*, *187*, 770-779. https://doi.org/10.1016/j.jclepro.2018.03.236

Peng, W., Xiaoyuan, Y., & Haron, N. A. (2025). Relative improvements between roads and railways and transport carbon dioxide emissions: An EKChypothesis test in China. *Sustainable Futures*, *9*, 100520. https://doi.org/10.1016/j.sftr.2025.100520

Sadorsky, P. (2011). Financial development and energy consumption in Central and Eastern European frontier economies. Energy policy, 39(2), 999-1006. https://doi.org/10.1016/j.enpol.2010.11.034

Sadorsky, P. (2014). The effect of urbanization on CO2 emissions in emerging economies. *Energy economics*, *41*, 147-153. https://doi.org/10.1016/j.eneco.2013.11.007

Saidi, K., & Mbarek, M. B. (2017). The impact of income, trade, URB, and FD on CO 2 emissions in 19 emerging economies. *Environmental Science and Pollution Research*, *24*, 12748-12757. https://doi.org/10.1007/s11356-016-6303-3

Saliminezhad, A., Ozdeser, H., & Birnintsaba, D. A. B. (2022). Environmental degradation and economic growth: time-varying and nonlinear evidence from Nigeria. *Environment, Development and Sustainability*, *24*(5), 6288-6301. https://doi.org/10.1007/s10668-021-01702-8

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*, *26*(5), 666-682. https://doi.org/10.1108/MEQ-05-2014-0063

Shafik, N., & Bandyopadhyay, S. (1992). *Economic growth and environmental quality: time-series and cross-country evidence* (Vol. 904). World Bank Publications.

Shahbaz, M., Li, J., Dong, X., & Dong, K. (2022). How financial inclusion affects the collaborative reduction of pollutant and carbon emissions: The case of China. *Energy Economics*, *107*, 105847.Council Countries robust?. *Renewable and Sustainable Energy Reviews*, *51*, 317-326. https://doi.org/10.1016/j.eneco.2022.105847

Shahbaz, M., Shahzad, S. J. H., Ahmad, N., & Alam, S. (2016). FD and environmental quality: the way forward. *Energy policy*, *98*, 353-364. https://doi.org/10.1016/j.enpol.2016.09.002

Shahzada, N., Kakar, A. K., Shah, Z., & Ahmed, N. (2025). Climatic Variation and Trend Analysis in Pakistan Using GIS Technique. *Present Environment & Sustainable Development, 19*(1). https://doi.org/10.47743/pesd2025191008

Sinha, A., Shahbaz, M., & Balsalobre, D. (2019). Data selection and EKCmodels-EKCmodels, data choice, data sources, missing data, balanced and unbalanced panels. In Environmental Kuznets

Curve (EKC) (pp. 65–83). Academic Press. https://doi.org/10.1016/B978-0-12-816797-7.00007-2.

Sohag, K., Al Mamun, M., Uddin, G. S., & Ahmed, A. M. (2017). Sectoral output, energy use, and CO2 emission in middle-income countries. *Environmental Science and Pollution Research*, *24*(10), 9754-9764. https://doi.org/10.1007/s11356-017-8599-z

Sun, Y., Li, M., Zhang, M., Khan, H. S. U. D., Li, J., Li, Z., & Anaba, O. A. (2021). A study on China's economic growth, green energy technology, and carbon emissions based on the Kuznets curve (EKC). *Environmental Science and Pollution Research*, *28*(6), 7200-7211. https://doi.org/10.1007/s11356-020-11019-0

Suri, V., & Chapman, D. (1998). Economic growth, trade and energy: implications for the environmental Kuznets curve. *Ecological economics*, *25*(2), 195-208. https://doi.org/10.1016/S0921-8009(97)00180-8

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and FD lead to environmental degradation: evidence from BRIC countries. *Energy policy*, *37*(1), 246-253. https://doi.org/10.1016/j.enpol.2008.08.025

Waheed, R., Chang, D., Sarwar, S., & Chen, W. (2018). Forest, agriculture, renewable energy, and CO2 emission. *Journal of Cleaner Production*, *172*, 4231-4238. https://doi.org/10.1016/j.jclepro.2017.10.287

Wang, Q., Wang, X., Li, R., & Jiang, X. (2024). Reinvestigating the Environmental Kuznets Curve (EKC) of carbon emissions and ecological footprint in 147 countries: a matter of trade protectionism. *Humanities and Social Sciences Communications*, *11*(1), 1-17. https://doi.org/10.1057/s41599-024-02639-9

World Bank (2021). World Development Indicators, Online Database.

Wu, Q., Chen, Y., Huang, C., Zhang, L., & He, C. (2025). Carbon emission peaks in countries worldwide and their national drivers. *Carbon Research*, *4*(1), 28. https://doi.org/10.1007/s44246-025-00195-8

Xie, L., Yan, H., Zhang, S., & Wei, C. (2020). Does Urbanization increase residential energy use? Evidence from the Chinese residential energy consumption survey 2012. *China Economic Review*, *59*, 101374. https://doi.org/10.1016/j.chieco.2019.101374

Yu, Y., Zhang, N., & Kim, J. D. (2020). Impact of Urbanization on energy demand: An empirical study of the Yangtze River Economic Belt in China. *Energy Policy*, *139*, 111354. https://doi.org/10.1016/j.enpol.2020.111354

Zhang, C., & Lin, Y. (2012). Panel estimation for Urbanization, energy consumption and CO2 emissions: A regional analysis in China. *Energy policy*, *49*, 488-498. https://doi.org/10.1016/j.enpol.2012.06.048

Zhang, M., Imran, M., & Juanatas, R. A. (2025, August). Innovate, conserve, grow: A comprehensive analysis of technological innovation, energy utilization, and carbon emission in BRICS. In *Natural resources forum* (Vol. 49, No. 3, pp. 2998-3021). Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1111/1477-8947.12510

Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological economics*, *68*(10), 2706-2712. https://doi.org/10.1016/j.ecolecon.2009.05.011

Zhang, Y. J. (2011). The impact of FD on carbon emissions: An empirical analysis in China. *Energy policy*, *39*(4), 2197-2203. https://doi.org/10.1016/j.enpol.2011.02.026