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# Analyzing the Impact of Urbanization on Carbon Dioxide Emissions: Fresh Evidence from Pakistan

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## Abstract

*Over several decades, unplanned urbanization is increasing $CO_2$ emissions due to higher energy demand from industrial activities, transportation, and waste management. The present study assesses the link between urbanization and $CO_2$ emissions in Pakistan from 1985 to 2020 by controlling FDI, access to electricity, and institution quality. The empirical results are estimated by using the ARDL approach while causality is extracted through the Granger Causality test. The empirical findings depict that urbanization leads to $CO_2$ emissions. Furthermore, institutional quality declines $CO_2$ emissions, while FDI and access to electricity significantly increase $CO_2$ emissions. The Granger Causality results indicate a bidirectional causality between electricity access and $CO_2$ emissions. At the same time, $CO_2$ emissions and urbanization show unidirectional causality. The study suggests that Pakistan needs to promote an environment-friendly energy consumption pattern.*

**Keywords:** Urbanization, CO2 emissions, FDI, Institutional Quality, ARDL

**JEL Classification:** P25, R11, Q53,

## 1. Introduction

As a result of a massive increase in social development and output growth, a considerable part of the workforce moves from the agriculture sector to urban areas for industrial jobs(Ge et al. 2020). It is associated with a drastic increase in energy consumption in urban areas which has provoked enormous challenges linked to environmental pollution (Parikh and Shukla, 1995). Additionally, the ongoing rise in carbon dioxide emissions ($CO_2$) is widely considered a severe threat prevailing to the global ecosystem. It is thought that metropolitan areas account for a significant portion of global $CO_2$ emissions. IEA states that the share of urban

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areas in the world's $CO_2$ emissions is around 70% from a production standpoint, and this figure is expected to rise to 76% by 2030 (Liu et al., 2022).

Urbanization (URPOP) has raised the concern of academicians and policymakers about the overlapping issues of rising climate change and mitigating environmental sustainability. Furthermore, the literature found that about 50% of the global population resides in cities, which is steadily expanding in developing nations. Unemployed people in rural areas typically relocate to cities in search of work, creating environmental issues in cities and adversely affecting infrastructure (Li et al., 2022: Asghar et al. 2022a,b). The number of vehicles on the road has been increasing over time, adversely impacting the climate. Bakhsh et al. (2018) state that climate change affects the urban population more due to metropolitan high-temperature island effects. Undoubtedly, urbanization is regarded as indispensable for economic growth, bringing innovation and new opportunities for the people. On the other hand, rapid urbanization tends to spread diseases and other problems such as offences, deprivation, and ecological pollution (for details, see Bloom et al. 2008).

Most industries near urban areas use fossil fuels, which negatively impacts the environment. The rapidly increasing urban population in emerging economies causes many problems, including the failure of sanitation and sewerage systems. In big cities, metropolitan authorities face many difficulties in providing safe drinking water to the urban population. Another issue that causes environmental problems is deforestation. Besides, Overcrowding, automobile exhaust, and industrial discharges in large cities significantly contribute to the enormously high environmental costs of urban crowding. The cultivated area shrinks with the increase in urban population, and the leftover elegant regions may not fulfil the population's needs (Amjad et al.,2021a).

Researchers have found a controversial point of view regarding urban growth and $CO_2$ emission. For example, some researchers point out that increased energy use generates toxic gases which cause environmental degradation (Cole and Neumayer, 2004). Others argue that urban expansion decreases energy needs by producing better infrastructure, i.e., public transportation and utility services reduce energy use and GHG emissions (Chen et al., 2008).

Institutional quality is an essential but often overlooked factor influencing environmental performance (Ibrahim and Law, 2016; Lau et al. 2014). The researchers advocated that better quality institutions in any country can reduce environmental degradation. Yandle et al. (2004) point out that both economic growth and environmental regulations accelerate together. The environmental quality will improve if there is a proper implementation of government regulations in the country. The above discussion confirms that institutional quality is highly important for environmental quality.

In general, urbanization positively influences human development, poverty, and economic growth (Nguyen, 2018). Urban residents are more educated and have plenty of job opportunities. Further, the urban areas serve as development hubs with the proximity of transportation, government, and commerce, providing infrastructure for information and knowledge sharing (United Nations, 2019). On the other hand, rapidly increasing urbanization leads to the degradation of the environmental quality in developing economies like Pakistan (Ahmed et al., 2019).

This study intends to analyze the influence of URPOP, FDI, institutional quality (IQ), and access to electricity (AE) on $CO_2$ emissions from 1984 to 2020. Pakistan's urban population has grown significantly since its inception. Hence, massive urbanization in Pakistan potentially threatens the environment and hurts the law and order, electricity, sanitation, and quality of education. The government of Pakistan (2017) reported that just 17.6% of the people were living in cities at the time of independence, and now it reached 55%. This rapid growth rate of the urban population has become a significant challenge to the environmental quality of Pakistan.

## 2. Review of Literature

Several pieces of literature examined the role of urbanization (URPOP) in environmental pollution. The researchers are divided on whether URPOP pollutes or improves environmental quality. The researcher who favours URPOP pollutes the environment argued that unplanned urbanization destroys natural resources due to traffic congestion, overcrowding, and industrialization. Cole and Neumayer (2004) inspected the connection between $CO_2$ emissions, demographic factors, and URPOP. The findings conclude that URPOP and demographic characteristics significantly enhanced carbon emissions in developing economies. Xu and Lin (2015) demonstrated the effect of URPOP on $CO_2$ releases in China by using non-parametric analysis from 1990 to 2011. The outcomes infer that URPOP leads to $CO_2$ emissions.

Bekhet and Othman (2017) inspected the link between financial development, URPOP, domestic investment, and $CO_2$emissions. The findings indicate that in Malaysia, unplanned urbanization escalated $CO_2$ emissions, while planned urbanization declined $CO_2$ emissions. Kurniawan and Managi (2018) inspected the linkages between output growth, trade, industry, URPOP and $CO_2$

emissions in Indonesia during 1970-2015. The outcomes revealed that output growth, trade, and urbanization enhanced the $CO_2$ emissions.

Salahuddin et al. (2019) studied African countries to check the causes of rapid urbanization. The study revealed that rapid urbanization is a major cause of $CO_2$ pollution. Ali et al. (2019) connected $CO_2$ with urbanization for Pakistan's economy. The study used ARDL bound test econometric technique for estimating the elasticities. Moreover, the results reveal that urbanization enhances $CO_2$ emissions in Pakistan.

Zeng et al. (2022) pointed out the impact of future URPOP on the concentration of carbon elements in Guizhou and the west of China. This study used urban growth patterns in four scenarios predicting CO2 emissions in the next fifteen years. It showed that urbanization initially increased $CO_2$ and then decreased it. Furthermore, in the next fifteen years, urbanization persistently increased.

Lee et al. (2023) assessed the role of URPOP on CO2 emissions from 1996 to 2018 in China. The study found that URPOP raised CO2 emissions, but the FDI inflows minimized this effect. Yang et al. (2023) studied terrestrial vegetation economies to examine the impact of URPOP on the environment from 2009 to 2018. The study explored that the URPOP contributed to CO2 emissions in the atmosphere of about 3.93 ppm. This amount of atmosphere concentration badly affects the environment.

Several studies argued that planned urbanization improves the environment by declining $CO_2$ emissions. In planned urbanization, the development of environmentally friendly transportation, protection of natural habitats, energy-efficient infrastructure, and clean energy resources played an essential role in controlling CO2 emissions. Hossain (2012) highlighted the association between URPOP, energy, trade, and $CO_2$ emissions in Japan. This study concluded that urbanization and trade considerably promoted the overall quality of the environment.

Ahmad and Majeed (2019) evaluated the synergy between URPOP and $CO_2$ emissions from 1990 to 2014 in South Asian countries. The FMOLS econometric technique was employed in the study to determine the long-run elasticities of coefficients. The empirical data demonstrated that traditional energy resources increased $CO_2$ emissions in these countries, whereas renewable energy and URPOP reduced $CO_2$.

Few studies examined the mixed effect of URPOP on $CO_2$. Azam and Khan (2016) highlighted the nexus between $CO_2$ and URPOP for SAARC economies, namely Pakistan, India, Sri Lanka, and Bangladesh, from 1982 to 2013. The findings implied that URPOP significantly and detrimentally impacts $CO_2$ concentration in India and Bangladesh. Alternatively, it increased Sri Lanka's $CO_2$ emissions.

Some studies show that FDI inflows from foreign countries to emerging states cause ecological pollution (see for example, Rahman and Ahmad 2019; Khan et al., 2020). Zhang et al. (2014) pointed out that FDI positively contributed in $CO_2$. Jain (2017) pointed out that international corporations and FDI cause considerable $CO_2$ in emerging states due to poor institutional and political structures. Similarly, Sarkodie and Strezove (2019) pointed out that the transfer of technology from advanced to growing states increases $CO_2$ emissions. Gorus and Aslan (2019) point out that FDI inflows contribute to $CO_2$emissions in the MENA region.

The available literature argues that the quality of institutions, such as an efficient bureaucracy, the rule of law, and the absence of corruption is critical in analyzing the growth-emissions nexus. After synthesizing the above literature, it is concluded that several studies have shown several determinants of $CO_2$ emissions. Despite the success of previous studies in certain areas, these continue to suffer from contradictory findings.

In the previous literature, numerous studies examined the role of URPOP on carbon emissions (Hossain, 2012; Azam and Khan, 2016; Bekhet and Othman, 2017; Ahmad and Majeed 2019). These studies examined the symmetric behaviour of urbanization carbon emissions. There is limited literature on the case of Pakistan.

## 3. Data and Description of Variables

For analysis purposes, annual data series has been used for Pakistan`s economy from 1984 to 2020. *$CO_2$ serves* as the explained variable, urbanization (URPOP) as the key explanatory variable, access to electricity (AE) (% of the population), FDI, net inflow (% of the GDP), and institutional quality (IQ). The functional form of the model is given below:

$$CO_2 = f\ (URPOP, FDI, IQ, AE) \qquad (1)$$

The current study converts all variables to natural log form to extract the long-run elasticities of coefficients and obtain accurate results.

$$LCO_{2t} = \beta_0 + \beta_1(LURPOP_t) + \beta_2(LFDI_t) + \beta_3(LIQ_t) + \beta_4(LAE_t) + u_t \qquad (2)$$

Where

$LCO_2$ emissions = Log of $CO_2$

LURPOP= Natural log of urbanization

LFDI = Natural log of FDI

LIQ= Natural Log of Institutional quality

LAE= Natural Log of access to electricity

In equation 2, $CO_2$ served as the dependent variable in our analysis, measuring per metric tons emissions in a specific year. The urban population (URPOP) is treated as a key explanatory variable, defined as the people living in big cities. FDI, AE, and IQ are used as control variables. The FDI shows foreign investment in Pakistan. AE is the percentage of the population having access to electricity. The above-discussed variables are taken from WDI-2021. The IQ is measured by using the proxy of government stability. It is made up of three parts: legislative strength, government unity, and popular support. The value of the index is ranged from 0 to 12. A low rating indicates very high risk, while a higher rating indicates very low risk (Amin et al., 2022). The data of IQ has been taken from ICRG.

The present study uses the ARDL estimation technique in econometric analysis. The ARDL model is.

$$\Delta LCO_{2t} = \beta_0 + \beta_1 LCO_{2t-1} + \beta_2 LURPOP_{t-1} + \beta_3 FDI_{t-1} + \beta_4 LIQ_{t-1} + \beta_5 LAE_{t-1} + \sum_{i=1}^{P} \beta_{1i} \Delta LCO_{2t-i} + \sum_{i=0}^{q} \beta_{2i} \Delta LURPOP_{t-i} + \sum_{i=0}^{r} \beta_{3i} \Delta LFDI_{t-i} + \sum_{i=0}^{s} \beta_{4i} \Delta LIQ_{t-i} + \sum_{i=0}^{t} \beta_{5i} \Delta LAE_{t-i} + \epsilon_t \quad (3)$$

The 1st difference of $\Delta LCO_{2t}$ represents the dependent variable, $\epsilon_t$ shows the error term and $\beta_0$ demonstrates the constant in the model. The short-run and long-run elasticities of coefficients could be calculated based on cointegration in the model. The error correction model is given below.

$$\Delta LCO_{2t} = \lambda + \sum_{i=1}^{P} \beta_{1i} \Delta LCO_{2t-i} + \sum_{i=0}^{q} \beta_{2i} \Delta LU_{t-i} + \sum_{i=0}^{r} \beta_{3i} \Delta LFDI_{t-i} + \sum_{i=0}^{s} \beta_{4i} \Delta LIQ_{t-i} + \sum_{i=0}^{t} \beta_{5i} \Delta LAE_{t-i} + \phi ECT_{t-1} + u_t \quad (4)$$

Where $ECT_{t-1}$ is the error correction term.

## 4. Results and Discussion

Table 1 shows the description of the concerned variables, i.e., $LCO_2$, LIQ, LFDI, LAE, and LURPOP are displayed in Table 1. The mean ($\overline{\boldsymbol{X}}$) values are greater than their SD values, meaning all the variables are under-dispersed (Rani et al., 2022a, b; Wang et al., 2022).

**Table 1. Descriptive Statistics**

| | LCO2 | LURPOP | LFDI | LIQ | LAE |
|---|---|---|---|---|---|
| Mean($\overline{X}$) | 5.014 | 0.503 | 0.983 | 0.823 | 0.268 |
| Median($\widetilde{X}$) | 5.010 | 0.480 | 0.772 | 0.829 | 0.268 |
| Maximum values | 5.343 | 0.620 | 3.668 | 1.035 | 0.273 |
| Minimum values | 4.632 | 0.423 | 0.178 | 0.336 | 0.266 |
| S.D | 0.200 | 0.068 | 0.793 | 0.148 | 0.002 |

Table 2 describes the correlation matrix between the variables. It helps to check the issue of multicollinearity. Table 2 ignores the 1st column because it shows the association of the explained variable with each explanatory variable. The remaining column shows the association between the explanatory variables, which is used to check the issue of multicollinearity in the model. It is noted that the absolute value of all pairs is less than 0.80, which shows no multicollinearity issue in this model (Amjad et al., 2021).

**Table 2. Correlation Analysis**

| Variables | LCO2 | LURPOP | LFDI | LIQ | LAE |
|---|---|---|---|---|---|
| LCO2 | 1 | | | | |
| LURPOP | -0.962 | 1 | | | |
| LFDI | 0.355 | -0.320 | 1 | | |
| LIQ | 0.262 | -0.220 | 0.161 | 1 | |
| LAE | -0.126 | 0.208 | -0.286 | -0.307 | 1 |

Source: Authors' own calculations

Table 3 shows the ADF unit root test to check the variables' co-integration order. It shows that the variables are of mixed order of integration. It guides us that ARDL is a proper estimation technique for our model.

**Table 3: ADF unit root test**

| Variables | Level | 1st diff. | Decision |
|---|---|---|---|
| LCO2 | -0.018 | -0.085*** | I(1) |
| LURPOP | -0.016 | -0.341*** | I(1) |
| LFDI | -0.287*** | | I(0) |
| LIQ | -0.195** | | I(0) |
| LAE | 0.048 | -0.556*** | I(1) |

Source: Authors' own calculations

The first step in using the ARDL approach is to confirm the cointegration among the variables. For this purpose, a bound test is applied.

**Table 4. Bound Test**

| F-Statistics | | 7.089 |
|---|---|---|
| Level of Significance | Lower Bound | Upper Bound |
| 10% | 2.45 | 3.52 |
| 5% | 2.86 | 4.01 |
| 1% | 3.74 | 5.06 |

Note: At a 1% level of significance

The bound test results are presented in Table 4, which confirms the long-run relationship between the variables. The primary objective of this study is to inspect the symmetric impact of URPOP on $CO_2$ for Pakistan's economy. For estimation purposes, ARDL has been used in Table 5.

**Table 5. ARDL Results**

| Variables | Coeff. | Prob. |
|---|---|---|
| | Short Run Results | |
| $\Delta$LURPOP$_t$ | -0.465* | 0.000 |
| $\Delta L$FDI$_t$ | 0.006*** | 0.091 |
| $\Delta$LIQ$_t$ | 0.058*** | 0.072 |
| $\Delta LIQ_{t-1}$ | 0.060 | 0.115 |
| $\Delta LAE_t$ | -0.745 | 0.384 |
| $\Delta LAE_{t-1}$ | 0.782 | 0.139 |
| $\Delta LAE_{t-2}$ | 0.836 | 0.164 |
| ECT (-1) | -0.124* | 0.000 |
| | Long Run Results | |
| LURPOP | 0.585* | 0.000 |
| LFDI | 0.066*** | 0.081 |
| LIQ | -0.814* | 0.001 |
| LAE | 1.924 | 0.105 |

Note: *, **, and *** show 1%, 5% and 10% significance level

In Table 5, in short-run coefficients, ECT indicates the adjustment rate toward equilibrium after the economy has experienced an economic shock. Moreover, the ECT coefficient is significant and carries a negative sign which reveals the long-run link between LURPOP and L$CO_2$. The empirical results show that an increase in LURPOP considerably declines $LCO_2$. Further, the results highlight that LIQ and LFDI are both positively connected with $LCO_2$ in the short run.

The lower part of Table 5 shows the long-run coefficients of the ARDL. The long-run turnout demonstrates that LURPOP has a substantial and positive connection with $LCO_2$ in Pakistan. For instance, the results explore that a 1% increase in LURPOP enhances $LCO_2$ by approximately 0.585% at a 1% significance level Furthermore, the LIQ considerably mitigates $LCO_2$. It depicts that a 1% improvement in the IQ declines $CO_2$ emissions of about 0.814% in Pakistan. Moreover, LFDI is positively connected with $LCO_2$. However, the effect of AE on $CO_2$ appears insignificant.

The diagnostic test results are shown in Table 6, proving the validity of our model since all outcomes passed diagnostic tests.

**Table 6. The Diagnostic Tests**

| Tests | Test-Stat. | Prob. |
|---|---|---|
| Normality Test | 0.185 | 0.972 |
| BP Test | 0.315 | 0.974 |
| LM Test | 0.636 | 0.539 |
| RESET | 0.168 | |
| $R^2$ | 0.994 | |
| Adj. $R^2$ | 0.992 | |

Figures 3 and 4 show CUSUM and CUSUMSQ tests showing that our model is stable.

**Figure 3. CUSUM Test**

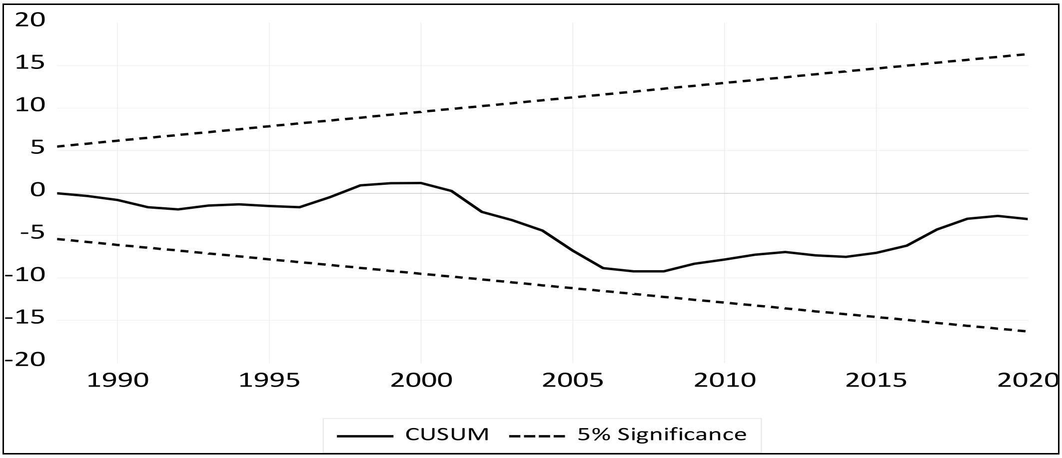


**Figure 4. CUSUM Square Test**

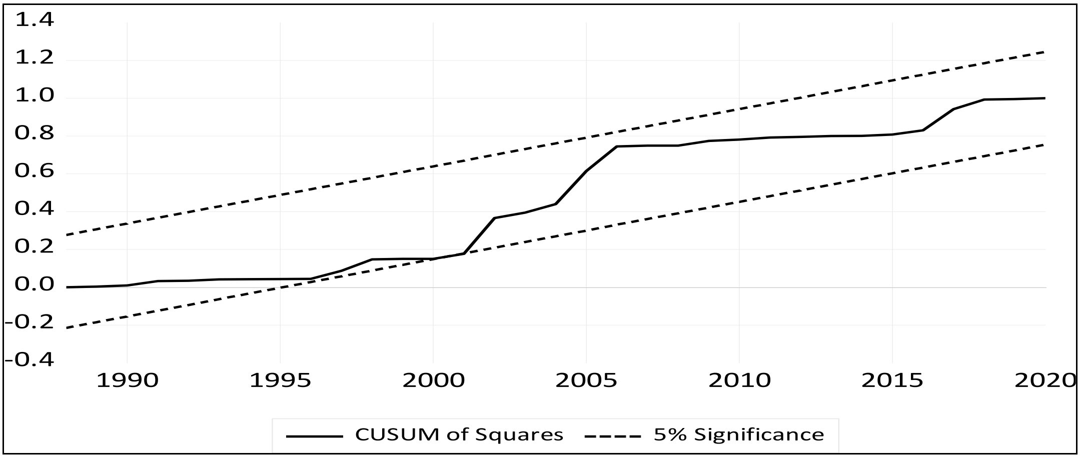


Table 7 summarizes the findings of the symmetric causal analysis. The empirical results from the Granger Causality test indicate that there exists a unidirectional causality from $CO_2$ emissions to U. Additionally, the results demonstrate that a unidirectional causal connection is valid from FDI to $CO_2$ emissions, IQ to carbon discharges, and AE to IQ. However, the findings depict that bidirectional causal linkage exists between AE to $CO_2$ emissions and AE to URPOP.

**Table 7. The Causality Analysis**

| Null Hypothesis: | F-Statistic | Symmetric Causality |
|---|---|---|
| LURPOP➔$LCO_2$ | 1.599 | No |
| $LCO_2$ ➔ LURPOP | 3.821*** | Yes |
| LFDI ➔$LCO_2$ | 2.581* | Yes |
| $LCO_2$ ➔ LFDI | 0.289 | No |
| LIQ ➔ $LCO_2$ | 6.653*** | Yes |
| $LCO_2$ ➔LIQ | 0.661 | No |
| LAE ➔$LCO_2$ | 3.351*** | Yes |
| $LCO_2$➔ LAE | 3.621*** | Yes |
| LFDI ➔ LURPOP | 0.646 | No |
| LURPOP ➔ LFDI | 0.922 | No |
| LIQ ➔ LURPOP | 1.570 | No |
| LURPOP➔LIQ | 0.368 | No |
| LAE ➔LURPOP | 2.881* | Yes |
| LURPOP ➔LAE | 7.745*** | Yes |
| LIQ ➔LFDI | 0.756 | No |
| LFDI ➔LIQ | 0.054 | No |
| LAE ➔LFDI | 1.092 | No |
| LFDI ➔LAE | 0.394 | No |
| LAE ➔LIQ | 2.627* | Yes |
| LIQ ➔LAE | 0.0645 | No |

Note: *, **, and *** show significance at 1%, 5%, and 10%, respectively

## 5. Conclusion and recommendation

The main objective of this study is to analyze the impact of urbanization (URPOP) on $CO_2$ emissions for the period 1984-2020 in Pakistan. The study incorporated some control variables in empirical analysis: FDI, IQ, and AE. The findings from ARDL depict that an increase in URPOP meaningfully stimulates $CO_2$ emission in Pakistan. FDI also plays a significant role in the contribution of CO2 concentration in the atmosphere. It shows Pakistan attracts FDI without caring about the environment. A few multinational corporations (MNCs) relocate their manufacturing units to Pakistan to save the pollution emissions in their home countries. Because their home countries have higher environmental standards; as a result, the ecological quality in Pakistan deteriorates. Furthermore, in Pakistan, institutional quality (IQ) mitigates $CO_2$ concentration. It shows that better IQ motivates the manufacturing sector to adopt environmentally friendly technologies, ultimately reducing CO2 concentrations.

Based on the empirical findings of ARDL, the study suggests that URPOP emitted a higher concentration of $CO_2$ that pollute Pakistan’s environment. Hence, this study suggests that Pakistan should pay proper attention to shifting the industries out of cities and motivating them to use green technologies. The government of Pakistan should make a policy to use electric vehicles inside the cities. The policymakers and government may focus on the revival of public transportation in the country that can help improve environmental quality.

There are some drawbacks to this study. This research is focused on a single country, but it can be extended to several countries using the panel data technique, which may provide a clear picture of the relationship between the variables in the model.

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