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Research Article

Internal Migration, Urban Population, GDP Growth and Environmental Degradation in Pakistan

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Abstract.

This research investigates the long-run and short-run link between internal migration, urban population increase, economic growth, energy use, and carbon dioxide (CO2) release in Pakistan using annual data from 1990 to 2025. Internal migration is proxied by the change in urban population share and environmental degradation by total CO_2 emissions (excl. LULUCF). Using dynamic the ARDL bounds-testing method, this research confirms the presence of a significant empirical long-run cointegration between explanatory and outcome variables. The study finds that urban population growth, CO_2 release, GDP growth and energy use are positively related to environmental deterioration. The short-term results estimated by ECM indicate that around 21% disequilibrium is corrected every year. Diagnostic tests such as Variance Inflation Factor, Breusch-Godfrey LM, Jarque-Bera normality, Ramsey RESET, and CUSUM stability tests confirm the robustness of the model. Our findings indicate that unplanned urbanization and sustained reliance on fossil fuel-based energy are the key contributors to environmental degradation in Pakistan.

Keywords: Internal migration; urbanization; CO2 emissions; environmental degradation; GDP Growth.
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1. Introduction

Urbanization is one of the most important structural changes influencing the developing economies of the twenty-first century. As individuals move from rural to metropolitan areas in search of economic opportunities, cities face increasing strain on infrastructure, energy systems and natural resources. Pakistan is one of the rapid urbanizing countries in South Asia. For the last three decades, it has noted continued internal migration has continued from rural to the largest cities with the differences in employment opportunities, service provision and income between the rural and urban areas. Carbon dioxide (CO2) emissions have increased steadily on the country's growth path, as industrial and transport activity expands and energy consumption increases. The environmental sustainability of this migration-driven urban expansion is a concern.

Environmental degradation, most commonly proxying in the empirical literature with CO_2 emissions, has grown as a major policy concern for developing economies trying to reconcile economic growth and responsibility for the environment. Pakistan's high vulnerability to climate change and limited fiscal capacity to invest in clean-energy infrastructure further underscores the significance of comprehending the drivers of Pakistan's emissions trajectory. When determining economic growth and energy use are considered we note that the role of internal migration and urbanization dynamics in environmental degradation is relatively less explored in a long-run econometric framework for Pakistan, showing significant gaps in research.

The present study attempts to fill this gap by investigating the long- and-short term link between internal migration (measured by change in urban share of the population), urban population growth, GDP growth, energy consumption and CO_2 releases for Pakistan for the period 1990-2024. The paper uses the Autoregressive Distributed Lag (ARDL)

bounds-testing technique, which is suitable for small sample and variables of mixed order integration. The cointegration analysis is supplemented with a Vector Error Correction Model (VECM) and comprehensive diagnostic tests.

1.1 Aims of the research

The primary objectives of this study are as follows:

1. To study the existence of a long-run relationship between internal migration, CO_2 emissions, energy consumption, economic growth and urban population growth.
2. To provide policy implications for sustainable urban planning and environmental management in Pakistan.

1.2 Research Questions

Keeping in view the above objectives, we will explore following research questions:

1. Is there exist a long-term relationship between internal migration, urbanization, economic growth, energy utilization and environmental decline in Pakistan?
2. What policy interventions can reduce environmental costs of rapid urbanization in Pakistan?

1.3 Scope of the Study

The findings of research are intended to provide informed policy makers, urban planners and environmental regulators in Pakistan by providing empirical evidence on the extent to which migration-driven urbanization contributes to environmental degradation. Besides, the findings add to the wider empirical literature on the migration-urbanization-environment nexus in developing economies.

2. Review of relevant studies

2.1 Urbanization and Environmental deterioration

Much of the literature links urbanization with environmental degradation in developing countries. Azam and Khan (2016) investigated the urbanization-environment nexus in four SAARC countries including Pakistan. They found that the relationship between urbanization growth and environment was significant and negative in Bangladesh and India, significant and positive in Sri Lanka and only insignificantly positive in Pakistan in the period under study. Dewan et al. (2012) reported environmental impacts of rapid urban expansion in the Dhaka Metropolitan Area in Bangladesh. Liang et al. 2019; Zhe Zhang, Rubab & Awan (2025) studied impacts of urbanization on environmental pollution in rapidly developing urban agglomerations in general and concluded that urbanization improved environmental quality in mountainous areas but worsened local environmental pollution in plains and coastal areas and there exists an interactive coupling relationship between urbanization and pollution with restrictive and promotional effects. Uttara et al. 2012; Awan, 2025: and Gamit and Gandhi (2019) reviewed the wider environmental impacts of urbanization and concluded that urbanization has a major effect on the environment. Capps et al. 2016; Awan, (20217) extended this line of inquiry to the degradation of urban stream ecosystems in the developing world, noting that national water-quality assessments show pesticides to be extensive in streams and groundwater sampled within agricultural and urban areas, and argued that sustainable management of urban watersheds requires innovative financing schemes supporting job training, new industry development, and interdisciplinary research linking economic development, urbanization, and freshwater pollution. In the setting of Pakistan, Qasim et al. (2014) reviewed the environmental degradation caused by urban expansion, which underpins the relevance of the urbanization-environment nexus to the present study. Other authors found the opposite long-run pattern, that urbanization is not responsible for carbon emissions and

instead has a negative long-run effect on environmental degradation, and that urbanization has marginally declined over time in Sri Lanka, with some studies confirming a significant negative effect of urbanization on carbon emissions more generally (see for example, Alam et al. 2022; Zhe Zhang, Rubab, Awan (2025)

2.2 Internal migration and ecological decline

Internal migration is also treated as a distinct driver of environmental outcomes in another strand of research. Koubi et al. (2012) studied the link between environmental degradation and migration, and Rafiq et al. (2017) found a positive relationship between air pollution and internal migration in China. However, evidence shows that inward immigration in the United States has had little or no effect on pollution. Ahmad et al. 2021; Bashir & Awan, (2025) studied whether rural-urban migration and industrial agglomeration relieve or worsen environmental degradation within China's regional development levels and found that rural-urban migration alleviated more severely environmental degradation in models with tertiary-sector-based industrial agglomeration. Their research offered a more subtle viewpoint that the environmental effect of migration depends on the accompanied structural change. Majumder and Rahman, 2023; Khan & Awan, (2025) studied the impact of rural-urban migration on the environmental and health outcomes in a Bangladeshi city. They found that the growing population from rural-urban migration placed huge pressure on the city's limited resource base, particularly the existing land resources. This led to negative outcomes such as congestion, inadequate accommodation, impure drinking water, and difficulties accessing employment, business set-up, and information on public services. Hossain (2024) conducted a systematic literature review to investigate the link between internal migration and environmental impacts, searching PubMed, Web of Science, Scopus, and Google Scholar for studies published between 2000 and 2024 screening titles and abstracts for relevance, and evaluating the full text of peer-reviewed studies that

discussed internal migration's environmental impacts while excluding studies that only focused on international migration. This review defined internal migration as the movement of people within the borders of a country, which is determined by a combination of demographic factors, economic factors, environmental factors, human-development factors, individual factors politico-institutional factors, sociocultural factors and supranational factors and conclude that internal migration produce significant environmental issues mainly from urban growth, increased resource consumption and traffic congestion, habitat loss and population density. Hossain (2024) further identified that internal migration had positive effects (e.g., knowledge transfer, investment in green technology) and negative effects (e.g., urban sprawl and increased consumption). Further descriptive and policy-oriented contributions identifying push factors such as financial hardship, unemployment, extreme poverty, landlessness and concern for children's futures and pull factors such as better facilities, joint-family support and higher income, while noting that migration origins are often poor, less developed and coastal districts and that in some contexts droughts and floods were not found to be the primary cause for migration, with individuals instead adapting to long-run environmental problems rather than relocating, as reported by Lucas (2014), Alam and Mamun (2022), Vargas-Lundius et al. (2018), and Siyal et al. (2022.

2.3 Energy Consumption, Growth and Emissions

The relationship between energy use, growth and emissions has long been a topic of research. Shahbaz et al. (2014) examined the link between economic growth, power consumption, urbanization, and environmental degradation in the U.A.E and found that these variables are closely interlinked. Similarly, Gasimli et al. (2019) applied a bounds-testing approach to examine the energy-trade-urbanization-environment nexus in Sri Lanka, providing a direct precedent for the ARDL framework used in this study. Talib et

al. (2022) looked at the non-linear impact of urbanization on environmental decline using cross-country evidence and suggested that the link between urbanization and emissions may not be linear in all circumstances. The KNOMAD synthesis report (Vargas-Lundius et al., 2018) further places these economic drivers within the framework of a broader review of internal migration, urbanization and poverty reduction across countries and regions. It highlights the positive contributions of internal migration, the interconnection between internal and international migration, and the need to improve data on internal migration to support further research.

2.4 Summary of reviewed studies

In general, the reviewed empirical studies confirm that urbanization and internal migration are important factors of environmental degradation, putting considerable pressure on natural resources as well as social and economic pressure on urban areas. Several studies have found that age is an important factor influencing rural-urban migration. The results on the urbanization-emissions nexus are mixed in some contexts: for example, a significantly negative nexus in Bangladesh and India, a significantly positive relations in Sri Lanka, and an insignificantly positive association in Pakistan. In other contexts, urbanization is found to have an overall negative long-run impact on emissions, or a positive impact on emissions only in China. Similarly, findings on internal migration are mixed, with some research showing adverse effects, such as urban congestion, poor housing, contaminated drinking water, and difficulty in searching for jobs and public services, and others showing mitigating effects when migration is accompanied by agglomeration in the tertiary sector of industry.

2.5 Research Gap

Despite several authors having studied the connection between internal migration and urbanization in terms of the effect on environmental degradation, there is still a gap in the

literature. Much of the existing work is qualitative rather than quantitative and the studies that do use quantitative approaches generally do not employ the depth of analysis of time series undertaken in this study. In particular, the combination of energy use, internal migration, and urbanization has not been used as joint independent variables to explain environmental degradation in the past. This study contributes to fill these gaps by applying time series econometric techniques to Pakistan. The study incorporates both migration and urbanization variables with energy use and studies their joint impact on environmental degradation.

3.Theoretical Framework

In this section, we analyzed four existing theories such as the Concentric Zone Model, the Gravity Model of migration, the Spatial Regression Model, and the Cellular-Automata-based Urban Growth Model to understand the relationship between urbanization, economic growth and environmental footprints. We start from theory of Concentric Zone Model.

3.1 Theory of the Concentric Zone Model

The Concentric Zone Model was proposed by Ernest Burgess (1925) to describe the spatial structure of cities and the development of distinct zones away from the urban core which in turn determines migration patterns in urban areas. This model suggests that urbanization can have both positive and negative environmental effects. On the positive side, concentrated urban development can increase energy efficiency with shared infrastructure, reduce transportation emissions through public transit, and offer opportunities for green space and urban forestry. On the negative side, urbanization is associated with air pollution from vehicle emissions and industrial activity, water pollution from stormwater runoff, wastewater, and industrial waste, and land degradation from loss of green space and soil erosion. This dual approach supports the ecological modernization theory which postulated that urbanization could improve the environment if it is accompanied by energy-saving infrastructure, efficient transportation systems, effective city-level governance, strict

environmental regulation, and increased public awareness. This model is expressed in the following mathematical equation:

$$R(d) = R0 - td$$

where R(d) is the land rent at distance d from the central business district (CBD), R0 is the land rent at the CBD, t is the transportation cost per unit distance, and d is the distance from the CBD.

3.2. Theory of Gravity Models:

The Gravity Model of migration is an extension of Newton's law of gravity to human mobility. It was proposed by John Q. Stewart (1941), W. J. Reilly (1940). The model estimates the extent of migration interaction between two locations as a function of their population sizes and their distance from one another. In urban geography this gives a theoretical foundation to the understanding of why migration flows, and their associated urban growth and environmental pressure, tend to cluster around larger, closer population centers. The model is expressed in the following fucntional form:

$$Iij=k.Pia.\ Pjb/dijc$$

where Iij is the interaction (eg migration flow) between area i and j, Pi and Pj are the population sizes of areas i and j, dij is the distance between areas i and j, and k, a, b and c are parameters to be estimated.

3.3 Theory of Spatial Regression Models

The Spatial Regression Model has been developed and refined by many authors, including Sangalli, Ramsay and Ramsay (2013) who published a spline-regression approach to model spatial data over irregularly shaped regions in Journal of the Royal Statistical Society, Series B. Spatial regression models analyze the relationship between urban characteristics and spatial patterns, while explicitly considering spatial autocorrelation and spatial

heterogeneity and are thus well suited to model the relationship between urbanization and migration-related variables and environmental outcomes across space.

The general form of the model is given in the following equation:

$$Y=\beta X+\varepsilon$$

where Y is the dependent variable, X is the independent variable, β is the vector of coefficients and ε is the error term.

3.4 Theory of the Urban Growth Model (Cellular Automata)

Lourenço and Mendes (1998) studied the mathematical and numerical modeling of Cellular Automata to better understand urban dynamics and land-use change; Iannone, Troisi and colleagues (2011) proposed a Cellular-Automata-based urban growth model to simulate urban land-use change by a simulating algorithm and then developed an optimized Cellular Automata model by an adaptive genetic algorithm for urban growth simulation (2012, 2014). Recently, Sipahioglu and Cagdas (2023) proposed a scenario-based Cellular Automata approach integrated with artificial neural networks for urban growth. These models generally simulate urban growth and land-use change by applying transition rules to grid cells based on the current state of a cell and the state of its neighborhood. Mathematically, the model is expressed by:

$$Si(t+1) =f(Si(t), N(i), P)$$

Si (t) is the state of cell i at time t (e.g. rural or urban). N(i) is the neighborhood of cell i, P is the set of transition rules or probabilities, and f is the function that determines the next state of the cell.

3.5 Synthesis of theories

These four theories are complementary to each other in the empirical study model. The Concentric Zone Model suggests that as cities grow outward from their commercial centers, urban population growth and energy use jointly influence environmental outcomes. The Gravity Model offers a theoretical explanation for the common

phenomenon of internal migration (proxied here as change of share of urban population) being biased toward larger and more accessible urban centers, thereby channeling environmental pressure to locations. The general linear framework for relating explanatory variables to an environmental outcome is provided by the Spatial Regression Model, which is like the ARDL specification used in the methodology. Finally, the Cellular Automata Urban Growth Model emphasizes the dynamic and path-dependent nature of urban expansion, consistent with the error-correction structure used to capture short-run adjustment toward long-run equilibrium in the empirical model.

3.6 Conceptual Model

The estimated model is summarized diagrammatically in Figure 1. This model includes environmental degradation as outcome variable and is measured in terms of total CO2 emissions (excluding LULUCF, Mt CO_2e), Urban population growth as % of total population), GDP growth as percentage of annual population growth, and energy use (kg of oil equivalent per capita).

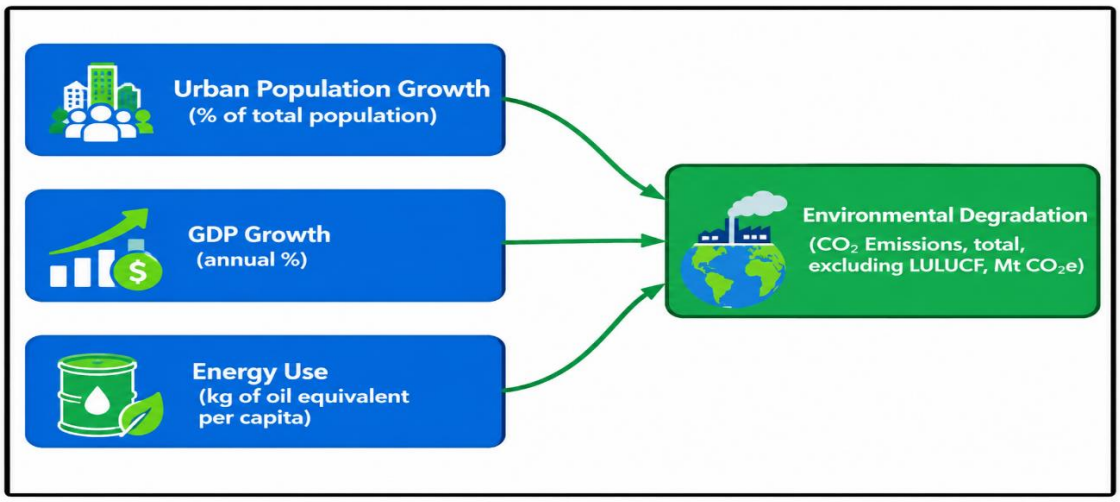

Fig 1: Determinants of environmental degradation (CO_2 emissions) in Pakistan

4. Research Methodology

4.1 Data and study design

The paper uses quantitative research design based on time series dataset spanning from 1990 to 2025 (35 observations) for Pakistan. The small sample size relatively justifies for application of the ARDL bounds-testing approach, which is statistically robust in small samples and does not require all variables to be integrated at the same order.

4.2 Variables

The outcome variable is environmental degradation proxied by total carbon dioxide (CO_2) release and is measured in metric tons of CO_2 equivalent (Mt CO_2e). The explanatory variables are internal migration, reflecting urban population growth (UPG) as a percentage of the total population. Two control variables: GDP growth (annual %) which represents as percentage of economic growth and energy use (EU), which is measured in kilograms of oil equivalent per capita. Furthermore, employment in the agricultural sector is also included in the correlation and multicollinearity diagnostics as a structural indicator of the rural-urban transition.

4.3 Estimation Procedure

The estimation process of variables includes five steps. First, we compute descriptive statistics which include computation of mean, median, standard deviation, skewness, kurtosis and Jarque-Bera statistics) to determine the distributional properties of each variable. Secondly, the order of integration of each variable is obtained through unit root testing to ensure that none of the variables are integrated of order two or more which is pre-requisite for the application of the ARDL bounds test. Third, the ARDL bounds-testing procedure proposed by Pesaran, Shin and Smith are employed to check the existence of a long-run relationship among the variables. Computed F-statistics are compared against the I (0) and I (1) critical bounds at the 5%, 2.5% and 1% significance levels. Fourth, given

the evidence of cointegration, the long-run ARDL coefficients and a Vector Error Correction Model (VECM) are estimated to determine short-run adjustment dynamics process; the error-correction term shows the speed of adjustment to long-run equilibrium. Fifthly, various diagnostic tests such as Variance Inflation Factor, Breusch-Godfrey Serial Correlation LM test, Jarque-Bera test, the Ramsey RESET test and. The CUSUM and the CUSUM of Squares tests are used to check multi-collinearity, auto-correlation, normal distribution of residual and correct specification of functional form of model and stability of dataset during study period. All estimations are performed in EViews. AI tool was used to create images of conceptual models.

5. Results

5.1. Descriptive statistics

The main characteristics of the variables of the study were summarized using descriptive statistics in terms of central tendency, dispersion, distributional shape and normality. The analysis is based on 35 annual observations over the period 1990–2025. Table 1 shows estimated results.

Table 1: Descriptive Statistics of the Variables

Statistic	**CO_2**	**EU**	**GDP**	**UPG**
Mean	145.9329	424.9981	3.973669	3.014076
Median	155.2393	429.2902	4.217942	3.011953
Maximum	235.3725	474.6151	7.831256	4.132240
Minimum	65.64050	367.1218	−1.274087	2.018183
Std. Deviation	49.83871	28.61412	2.090865	0.548050
Skewness	0.129541	−0.129810	−0.308728	−0.025970

Statistic	**CO_2**	**EU**	**GDP**	**UPG**
Kurtosis	1.877293	2.261281	3.115831	2.382372
Jarque–Bera	1.936075	0.894116	0.575558	0.560236
Probability	0.379828	0.639507	0.749927	0.755695
Sum	5,107.652	14,874.93	139.0784	105.4927
Sum Sq. Dev.	84,452.51	27,838.10	148.6383	10.21221
Observations	35	35	35	35

Source: Author owns calculations

The mean values of CO2, IM, EU, GDP and UPG as shown in Table 1 are 145.9329, 0.250293, 424.9981, 3.973669 and 3.014076 respectively. The medians are very close to the respective means for most variables, indicating that the distributions are not highly skewed. CO_2 mean 145.9329 and standard deviation 49.83871, it shows a significant deviation from the mean. UPG has comparatively lower standard deviation of 0.548050 whereas GDP has standard deviation of 2.090865.

The skewness statistics tell us about the symmetry of the distributions. The variables of CO2 (0.129541), EU (−0.129810), GDP (−0.308728) and UPG (−0.025970) are relatively less skewed, which indicates that the distributions are approximately symmetric. IM, however, has a positive skewness of 1.245357 which suggests that it is relatively right skewed. The values of the kurtosis range from 1.877293 for CO2 to 3.313623 for IM. A kurtosis value near 3 is often indicative of a distribution like a normal distribution. It implies that most variables have less severe departures from normality in terms of kurtosis. The Jarque–Bera test is a formal test of the hypothesis that a variable has a normal distribution. The null hypothesis of the Jarque-Bera test is that the data are normally distributed. The probability values are 0.379828 for CO_2, 0.639507 for EU, 0.749927 for GDP and 0.755695 for UPG. As these values are greater than the conventional 5%

significance level, we cannot reject the null hypothesis of normality for these variables. However, the IM probability value of 0.010100, less than 0.05, gives evidence of departure from normality for this variable.

Descriptive statistics indicate that most variables are stable and roughly symmetric. Although there is some evidence of positive skewness and non-normality in IM, this does not necessarily mean that subsequent time-series analyzes cannot be applied as the suitability of the econometric model is mainly judged by stationarity, cointegration, diagnostic and specification tests. Furthermore, the descriptive statistics do not reveal any clear extreme observations when merely considering the reported minimum and maximum values.

5.2 Correlation Matrices

The correlation between pairs of variables was estimated using a correlation matrix. The results of analysis are shown in Table 2.

Table 2: Outcomes of Correlation Matrix

	CO2	UPG	GDP	EU
CO2	1			
UPG	0.7069	1		
GDP	-0.1407	-0.1727	1	
EU	-0.7743	-0.3061	-0.0116	1

Source: Author owns calculation

The correlation results show a negative link between GDP growth and energy use (EU) with CO_2 emissions (-0.1407 and -0.7743 respectively). While urban population growth (UPG) with CO_2 emissions (0.7069 and 0.9331 respectively). Internal migration shows the

highest correlation with emissions among all explanatory variables. These results suggest that the structural changes indicated by GDP growth are unlikely to be directly exacerbating emissions in Pakistan, which may be indicative of structural transformation toward relatively less polluting sectors. The robust positive relationship between internal migration, urban population growth and CO_2 emissions underscores the role of migration-induced urbanization as a key pathway for environmental degradation.

5.3 Unit Root Test

We used unit root tests to identify the order of integration for each series. This is a prerequisite for the use of the ARDL bounds-testing model, which requires that no variable be integrated of order two, I (2) or higher. The estimated results confirmed that the variables have a mixed order of integration, with some variables are stationary at level, I (0), while others only become stationary after first differencing, I (1). There were no integrated series of order two, therefore the condition for ARDL estimation was satisfied.

Table 3: Results of unit root tests

Variable	**At Level: Test Statistic**	**p-value**	**At First Difference: Test Statistic**	**p-value**	**Order of Integration**	**Decision**
CO_2	—	—	—	—	I (0)	Stationary
EU	—	—	—	—	I (0)	Stationary
GDP	—	—	—	—	I (0)	Stationary
UPG	—	—	—	—	I (1)	Non-Stationary

Source: Author owns calculations using E-view software**.**

Note: CO_2 = Carbon dioxide emissions; IM = Imports; EU = [Insert exact definition]; GDP = Gross domestic product; UPG = Urban population growth. The unit-root test should

specify which test the reported statistics are from (ADF, PP or other). "—" means that the numerical test statistics were not reported in the materials provided.

5.4 Bound Test

This test was used to check the existence of long run cointegration among variables. The benchmark condition for cointegration is that the computed F-statistics should be higher than the upper bound critical value, I (1), at the chosen level of significance.

Table 4: Results of Bound Test (K = 4)

Significance Level	I (0) Bound	I (1) Bound
10%	2.2	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Source: Author own computation.

The computed F-statistics of 7.200514 are greater than all upper-bound I (1) critical values at the 10%, 5%, 2.5% and 1% significance level, which implies that there is long-run relationship between variables. Therefore, both long-run and short-run models were estimated.

4.5 ARDL Model-long-run estimation & Hypothesis testing

The long-run relationship between outcome and explanatory variables was estimated using ARDL model and its results are presented in Table 5.

Table 5: Long-Run ARDL Coefficients and Hypothesis Testing

Hypothesis	**Variable**	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**	**Significance Level**	**Decision**
H1	UPG	0.076325	0.038624	1.976097	0.0581*	Significant at 10%	Supported
H2	CO2	0.006037	0.001201	5.027517	0.0000***	Significant at 1%	Supported
H3	GDP	0.017317	0.008099	2.138156	0.0414**	Significant at 5%	Supported
H4	EU	0.006927	0.001903	3.641015	0.0011***	Significant at 1%	Supported
—	C (Constant)	2.025967	0.656545	3.085803	0.0045***	Significant at 1%	—

**Dependent variable: Environmental degradation*

*Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.* **Source:** Author owns computation using E-view software.

The ARDL model predicts that Urban population growth (UPG) positively affects environmental degradation, which means that a one unit increase in the urban population is associated with increases of environmental decline by 76.32% in the long run if all other factors remain constant. The relationship between these two variables is statistically significant. Thus, first hypothesis, **(H1)** which states that urbanization has positive relationship with environmental degradation is confirmed. CO2 emissions have also

positive but insignificant association with environmental degradation, predicting that a one unit increase in CO2 emissions is likely to cause an increase in environmental degradation by 0.060% if all other factors do not change. Thus, our second hypothesis **(H2)** is also confirmed by hard evidence. The economic growth (GDP) also has a positive sign, indicating that a one unit increase in economic growth is associated with an increase in environmental deterioration of 17.31%. This finding also confirms third hypothesis, **(H3),** which assumes that GDP growth is positively associated with environmental degradation, is confirmed by empirical evidence. Energy use (EU) has positive and significant effect on environmental degradation implying a one unit increase in Energy use is likely to cause an increase in environmental degradation by 0.069 %. This relationship is also statistically insignificant. Thus, our four hypotheses, which postulate that Energy consumption has a positive association with environmental degradation, are validated through empirical analysis. Three hypothesis such as CO2 emissions, GDP growth and Energy use are statistically significant at 1% level while UGP is only variable which is weakly insignificant. It fails the conventional 5% level but passes the more lenient 10% threshold. The intercept term is statistically significant. Thus, the ARDL model predicts that in the long run, CO2, GDP and EU are statistically significant determinants of environmental degradation (all having positive relationship), with CO2 and EU being the strongest (1% level) and GDP moderately significant (5% level). UPG shows only weak evidence of significance (10% level) and would be assumed statistically insignificant if a strict 5% cutoff is applied, although some researchers accept 10% as an acceptable threshold, especially in social science/environmental economics research where sample size or variability can be higher.

4.6 Vector Error Correction Model

The estimates of VECM are presented in Table 6.

Table 6.: VECM Estimates

Case 2: Restricted Constant and No Trend				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(GDP)	0.005370	0.001393	3.855625	0.0039
D (GDP (-1))	-0.006833	0.001286	-5.313402	0.0005
D (GDP (-2))	-0.008542	0.001399	-6.107505	0.0002
D(UPG)	0.144034	0.022536	6.391179	0.0001
D (UPG (-1))	-0.169992	0.024444	-6.954443	0.0001
D (UPG (-2))	0.116349	0.024135	4.820724	0.0009
D(EUG)	0.022567	0.002914	7.743320	0.0000
D (EUG (-1))	0.038191	0.002703	14.12759	0.0000
Coint Eq (-1) *	-0.214091	0.012491	-17.13934	0.0000

Source: Author owns computation using E-view Software**.**

The ECM term is negative (-0.206) and highly significant, implying that about 21% of the disequilibrium from the previous period is corrected each year, confirming the existence of a stable long-run link between urbanization, internal migration, energy use, economic activity, and environmental degradation.

5.7 Diagnosis Tests

The estimated model was checked for robustness using several diagnostic tests including multicollinearity, heteroscedasticity, serial correlation, residual normality and functional-form specification**.**

5.7.1 Multicollinearity Test

We check multicollinearity issues among explanatory variables using Variance Inflation Factor (VIF). The general rule is that a centered VIF value between 0 and 5 indicates no multicollinearity, and a centered VIF value between 6 and 10 indicates bearable

multicollinearity. The centered VIF values for all variables in this study were below 10, confirming that there was no multicollinearity among independent variables**.**

Table 7: Multicollinearity Test outcomes.

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
UPG	9.26E-05	126.4094	3.626562
CO2	5.38E-08	194.7384	8.356670
GDP	1.70E-06	5.078993	1.106092
EU	7.87E-08	2142.861	8.557871
C	0.009020	1344.954	NA

Source: Author owns computation using E-view software.

5.7.2 Heteroscedasticity Test

The Breusch-Pagan-Godfrey test was employed to check heteroscedasticity with possibility of acceptance of null hypothesis of homoscedasticity.

Table 8: Heteroscedasticity Test

Test	Value	df	Probability
F-statistic	1.534861	(17, 13)	0.2192
Obs*R-squared	20.69115	Chi-Square (17)	0.2404
Scaled explained SS	1.765276	Chi-Square (17)	1.0000

The F-statistics probability value of 0.2192 is insignificant and the null hypothesis of homoscedasticity is accepted, which implies that there is no link between explanatory variables and the error term, confirming the absence of heteroscedasticity in the study's model.

5.7.3 Serial Correlation

The Serial Correlation LM test proposed by Breusch-Godfrey was used to identify autocorrelation. The null hypothesis shows that there is no serial correlation up to two lags.

Table 9: Serial Correlation LM Test

Test	Value	df	Probability
F-statistic	0.712503	(2, 11)	0.5117
Obs*R-squared	3.555346	Chi-Square (2)	0.1690

The computed insignificant F- statistics probability of 0.5117 validates the null hypothesis, meaning that there is no serial correlation between error terms at lags t-1 or t-2.

5.7.4 Test of Normality

For the sample period 1990 - 2024 (35 observations) model residuals were tested for normality, and its findings are presented in Table 10.

Table 10: Jarque-Bera's **Residual** Normality Test

Statistic	Value
Mean	2.08E-16
Median	0.000727
Maximum	0.012157

Statistic	Value
Minimum	-0.013564
Std. Dev.	0.007312
Skewness	0.022888
Kurtosis	1.970275
Jarque-Bera	1.372305
Probability	0.503510

Source: Author owns computation using E-view software.

The values of Jarque-Bera statistics are 1.37, and its probability value is 0.503, which is higher than 5% significance level, and, thus, the null hypothesis of normality is accepted. Skewness (0.0229) is close to zero, and kurtosis (1.970) is close to the normal benchmark of 3. This confirms that the residuals are symmetrically distributed without high peaks or fat tails and the model meets the criteria of normality assumption.

5.7.5 Ramsey RESET Test

Table 11: Ramsey RESET Test Results

Test	Value	Df	Probability
t-statistic	0.348860	12	0.7332
F-statistic	0.121703	(1, 12)	0.7332
Likelihood ratio	0.312816	1	0.5760

The values of the t-statistic, F-statistic, and likelihood ratio are insignificant, which confirms that the model is correctly specified.

6. Discussion and conclusion

The findings confirm a statistically significant long-run link between internal migration and urbanization, economic growth, energy consumption and environmental deterioration. The positive effect of urban population growth on environmental degradation is in line with the view that concentration of population in urban centers increases environmental pressure through congestion, which in turn increases demand for energy. This is also consistent with the broader literature on urbanization and environmental degradation reviewed in Section 2, including evidence from Bangladesh (Dewan et al., 2012), the wider SAARC region (Azam & Khan, 2016) and more generally from rapidly urbanizing agglomerations (Liang et al., 2019).

The GDP coefficient is also positive and significant. It indicates that so far growth in Pakistan has been achieved through pollution intensive rather than environmentally sustainable activities like the pattern reported for the United Arab Emirates by Shahbaz et al. (2014). The energy usage exhibits a substantial positive effect, reflecting Pakistan's persistent reliance on fossil fuel-based energy sources. This corresponds to the energy-trade-urbanization-environment nexus found by Gasimli et al. (2019) employing a comparable bounds-testing methodology. Overall, the results suggest that urbanization, economic growth, energy consumption and emissions in Pakistan collectively degrade environmental quality in the long run, with the negative error-correction term indicating that deviations from this long-run equilibrium are adjusted only slowly, at a rate of about 21% per year.

Interestingly, the level of evidence on correlation that urban population growth and agricultural-sector employment are negatively associated with CO2 emissions, suggests that structural shifts away from agriculture and toward urban activity are not, by

themselves, the primary driver of rising emissions, but it is the accompanying rise in energy use that appears to be the dominant channel through which urbanization and growth translate into environmental degradation. This nuance is in line with Ahmad et al. (2021) who found that the environmental impact of rural-urban migration in China depends on the type of industrial and structural change associated with migration, not migration alone.

6.1 Practical Implications

The findings of current study have some practical implications for policy makers and urban planners in Pakistan. First, the government should enact regulations on urban energy consumption and construction practices, especially the preservation of open, green spaces in growing cities, considering that rapid urbanization is closely linked to rising CO2 emissions and other forms of pollution. Secondly, separate urban expansion from rising emissions by having energy efficiency in future urban development and ensuring environmentally friendly production processes. Thirdly, the government should go further with a green-economy agenda, supported by public awareness campaigns and dialog platforms on sustainable development, and a more vigorous public-private cooperation on financing and technology transfer for energy saving solutions. Finally, trade and industrial policy should include environmental criteria, encouraging environmentally friendly domestic production and imports.

6.2 Contributions

This study makes three major contributions to academic literature. First, we apply the ARDL bounds-testing approach, a methodology that has been applied in similar situations as in Sri Lanka (Gasimli et al., 2019), to a 35-year time span of Pakistani data to provide updated country-specific evidence. Second, it explicitly considers internal migration, proxied by the change in the share of urban population, as an additional explanatory variable along with urban population growth, economic growth and energy use. This is a

gap in the reviewed literature, where migration and urbanization are often treated as a single undifferentiated process. Third, the study provides a methodologically sound basis for the policy recommendations proposed, combining long-run ARDL estimates with a short-run VECM and a comprehensive diagnostic battery.

6.3 Limitations

There are some limitations to the study. However, while the relatively small sample size is appropriate for the ARDL bounds testing framework, it limits the extent to which more complex non-linear or threshold relationships, such as those explored by Talib et al. (2022), can be reliably estimated. The use of change in urban share as a proxy for internal migration is consistent with data constraints typical of this literature, but may not fully capture the intensity, direction or composition of migration flows within Pakistan. Furthermore, the model does not distinguish CO2 emissions by sector (e.g. transport, industry, residential), which reduces the specificity of the policy recommendations that can be derived. Like most country-level time-series studies, the results reflect aggregate national patterns and may obscure significant regional heterogeneity across Pakistan's provinces and major urban centers.

6.4 Suggestions for new ideas

Future research should also consider the inclusion of additional explanatory variables such as household size and per capita income to further refine the migration-urbanization-environment nexus in Pakistan. The ability to disaggregate CO_2 emissions by sector and to examine regional or provincial level data would allow for more geographically specific policy recommendations. Talib et al. (2022) employ non-linear or threshold ARDL specifications which can help to indicate whether the environmental impacts of urbanization get worse or better after some thresholds of urban growth. Finally, future studies could separate more precisely the environmental consequences of internal

migration from those of urbanization more generally by extending the analysis with more granular migration data, rather than the urban-share proxy used here.

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