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Pakistan's Green Puzzle: How Income, Clean Energy and People Affect the Environment, and the Role of Education in Shaping a Greener Future

Masroor Ahmed*
Department of Electrical Engineering, Bahria University, Islamabad, Pakistan
E-mail: masroorwafagolo18@gmail.com

Engr. Fahim Ahmed
Education and Literacy Department Government of Sindh, High School Kandhkot, Pakistan
E-mail: fahim.201122@gmail.com

Syed Safdar Ali Shah
Department of Management Sciences, Isra University, Hyderabad, Pakistan
E-mail: shahsafdarali69@gmail.com

Abstract:

The current paper analyzes the impact of GDP per capita, clean energy, total populations, and the educated population on ecological footprints. This Pakistani study utilizes time-series data from 1995-2020. Short-run findings from the ARDL bounds testing approach suggest that increasing per capita income raises ecological footprints, while in the long run, it decreases the same. Short-run and long-run coefficients are 0.766 and -0.909 respectively, indicating a one-unit increase in short-run income intensifies ecological footprints by 0.766 units, but in the long run, increasing per capita real GDP alleviates the pressure on natural capital by -0.909 units. Renewable energy use in Pakistan proves environmentally favorable, decreasing ecological footprints by -1.516 in the short run and -1.878 units in the long run. Conversely, a 1-unit rise in total population increases ecological footprints by 16.415 units in the short run and 0.479 units in the long run, suggesting a detrimental impact. Education emerges as a crucial factor, with an educated population reducing ecological footprints by -0.011 units in the short run and -0.004 units in the long run. The study recommends that Pakistan consider importing renewable energy technology and emphasizes the importance of educating populations about environmental concerns to address the risk of environmental collapse.

Keywords: *Income; Clean Energy; Population; Ecological Footprints; ARDL model; Pakistan.*

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* **Corresponding Author**

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Journal of Green Knowledge and Sustainable Development (JGKSD)

J. Grn. Knw. & Sus. Dev., Volume 1, Issue 1 (2024)

1. Introduction:

A clean environment supports the Earth's life system, where humans and other living communities, including plants and microorganisms, are interrelated as a single functional unit within the atmosphere (Friis, 2018). If one component of this complex bonding is disrupted, whether intentionally or unintentionally, the result might be the disturbance of entire ecosystems, potentially causing changes in the climate (Friis, 2018). As a result, world countries face ecological hazards such as repeated happenings of hurricanes, droughts, floods, and volcanic outbreaks (Ha & Dhakal, 2013; Iqbal et al., 2021). The underlined detrimental effects of the environment are particularly noticeable in vulnerable regions, leading to a significant decline in crop productivity. This, in turn, can result in food insecurity and a lack of access to clean drinking water. These environmental variations may contribute to issues such as nutritional deficiencies, short-term instability in the entire food system, and damage to health. These challenges pose a threat to progress toward a world without hunger, emphasizing the urgent need for sustainable and resilient solutions (Wheeler & Von Braun, 2013). Environmental Scientists have established that the Industrial Revolution is a key contributor to environmental instability, primarily due to the accumulation of hazardous gases(Ayobamiji & Kalmaz, 2020). Specifically, the levels of CO_2 have risen significantly, increasing from approximately 278.1 ppm during the pre-industrial Revolution era to about 403.3 ppm in 2016 (Ayobamiji & Kalmaz, 2020). This alarming shift underscores the profound impact of industrial activities on the Earth's atmospheric composition (Ayobamiji & Kalmaz, 2020). As a result, hundreds of millions of urban dwellers around the world have experienced weather-driven disasters(Akanwa & Joe-Ikechebelu, 2019). Those have financial, cultural, and ecological consequences on the societies. Nevertheless, while certain adversities arise naturally, some are the result of uncontrolled human activities. Examples include damaging the land, polluting water and air, depleting plant and animal species, utilizing timber for fuel, and the destruction of mangroves. These actions contribute to environmental degradation and underscore the need for sustainable practices to mitigate their impact (Agreement, 2015; WCED, 1987). Because the rising risk of ecological collapse is a key constraint to general development. Countries where people rely on natural resources are affected more by pollution, land degradation and other environmental problems (Wingqvist et al., 2012). Due to environmental deterioration, Pakistan has repeatedly been reported as a climate-vulnerable nation (Golo, Han, Ibrar, & Haroon, 2023). The country has faced severe consequences in the last few decades and lost billions of dollars in infrastructure and human losses due to environmental consequences (Dongping et al., 2023; Golo, Han, Ibrar, & Din, 2023; Golo, Han, Ibrar, & Haroon, 2023). Figures 1, 2, and 3 illustrate the statistical fact sheet about the Human and Economic losses in Pakistan due to environmental collapse, these fact sheets are evidence that natural hazards are the cause of the environmental collapse (Huppert & Sparks, 2006). Figures 4 and 5 reflect the pressure on nature, indicating environmental collapse.

Journal of Green Knowledge and Sustainable Development (JGKSD)

J. Grn. Knw. & Sus. Dev., Volume 1, Issue 1 (2024)

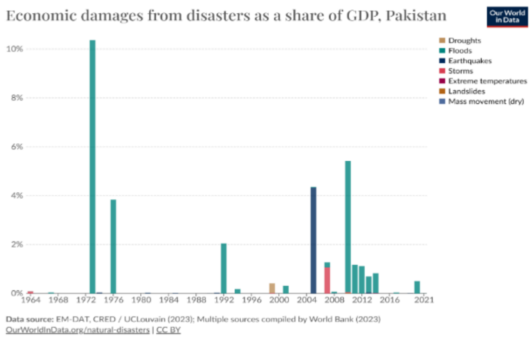

Figure 1. Economic Damage[1]

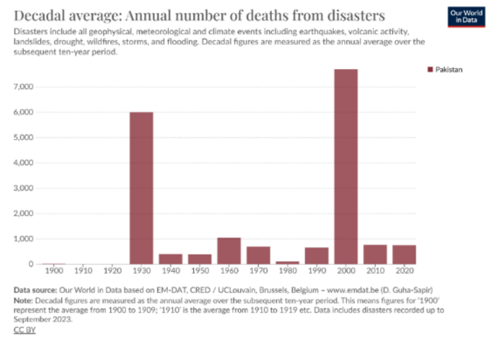

Figure 2. Human Losses[1]

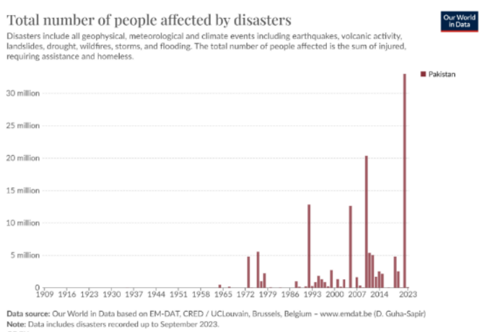

Figure 3. Natural Disasters[1]

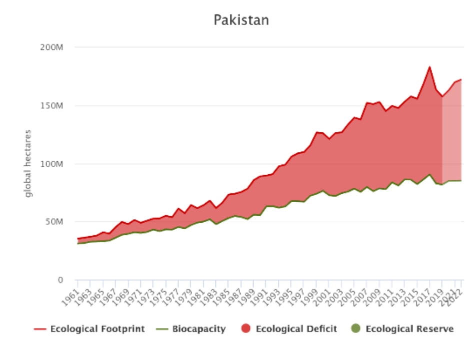

Figure 4. Ecological Footprints GHA[2]

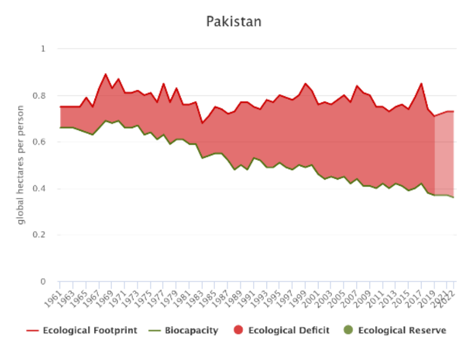

Figure 5. Ecological Footprints GHA per person[2]

Numerous studies have revealed that countries' industrial output is linked to an increase in ecological footprints (Chien et al., 2023; Jie et al., 2023). On the contrary, some studies have advocated the square of growth-associated determinants as a potential remedy for this issue, known as the Environmental Kuznets Curve (EKC) hypothesis (Golo, Han, Ibrar, & Haroon, 2023).

[1]https://ourworldindata.org/
[2]https://data.footprintnetwork.org/#/

However, the outcomes of EKC studies have varied across regions and countries (Hasan et al., 2023; A. Usman et al., 2023; Yilanci & Pata, 2020). Similarly, numerous studies have suggested that, along with economic growth factors, certain population aspects, including total population, could harm the environment (Abbas et al., 2020; Amin et al., 2023; Asongu et al., 2020; Jie et al., 2023; Saleem et al., 2018). The discrepancies in results can be attributed to dissimilarities in data structures, timespans, as well as regional diversity. Studies conducted in nations such as BRICS and global samples have shown that renewable energy alone may not decrease the harmful pressure on natural capital (Danish et al., 2020; Li et al., 2022). Therefore, the far-reaching impacts of environmental concerns have garnered significant attention from environmental scholars (Lv & Xu, 2019), emphasizing that the threats of unfavorable climate necessitate the establishment of safety provisions; otherwise, the costs of resulting damages would exceed current projections (Dongping et al., 2023). Given that the environmental sector alone cannot achieve ecological goals; therefore, all stakeholders should be taken on board (Lafferty & Hovden, 2003). Hence, this study not only inspects the influence of income, renewable energy use, and total population on ecological footprints but also analyzes the moderating impact of education as an interaction term with the total population in Pakistan. In this vein, the set objectives of the current study are given below.

1. To examine the influence of per capita real GDP on ecological footprints.
2. To study the effect of clean energy use on ecological footprints.
3. To investigate the influence of the total population on ecological footprints.
4. To investigate the moderating role of education with total population on ecological footprints.

2. Literature Review:

The environmental hazards, given their threatening impacts on human societies, have emerged as a matter of significant concern. This is because they pose a threat to the basic rights of people around the globe, endangering the lives of millions of people, their health, and access to food and water (Wewerinke & Yu, 2010). While a substantial amount of literature on this subject is available, the aspects uncovered by this study are relatively rare. The defined objectives of this study guide us to explore the related literature under the following headings: i) Increasing GDP per capita shaping the environment, ii) Favorable Environmental Impact of Renewable Energy, and iii) Environmental influence of total population and education.

2.1. Increasing GDP per capita Influencing the environment.

Nature directly contributes to economic activities by providing essential inputs and indirectly by offering nature's serviceability (Anu et al., 2024; Iliopoulos & Damigos, 2024). However, economic activities which heavily reliant on resource exploitation at high intensities result in

Journal of Green Knowledge and Sustainable Development (JGKSD)

J. Grn. Knw. & Sus. Dev., Volume 1, Issue 1 (2024)

elevated levels of harmful emissions, leading to the unsustainable use of ecosystems (Ali et al., 2024; Shi et al., 2024). The examined results in China, for the period from 1997-2017 revealed that per person gross domestic product adversely influenced the efficiency of countryside ecological improvement (S. U. Khan & Cui, 2022). Interestingly, in the lower basin, GDP per capita showed a non-significant positive impact (S. U. Khan & Cui, 2022). Contrarily, a study involving 154 countries, employing linear and threshold panel regression techniques, revealed that there are no threshold values between per capita GDP and per capita CO_2. This suggests that the effects of GDP per capita on per capita hazardous emissions are nonlinear (Q. Wang & Li, 2021). In examining the cogency of the Environmental Kuznets Curve (EKC) hypothesis in the five influential member countries of G-20 from 1993 to 2017, the results revealed that initially, per capita income intensified carbon releases in the sample countries (Awan & Azam, 2022). A Chinese study found that per capita GDP harms the environment over a longer period, showing a mutual nexus with hazardous emissions (Aslam et al., 2021). Analyzing Pakistan from 1980 to 2018, the study, utilizing the long-run relationship technique and the Impulse Response Function, revealed that industrial and fiscal developments could deteriorate decoupling efforts. The study emphasized the need to replace Pakistan's polluted industrial stock with energy-efficient technology (S. Khan & Majeed, 2023). In conclusion, the reviewed literature emphasizes the intricate connection between monetary accomplishments and their ecological impacts. While some regions show negative effects of economic growth on sustainability, others exhibit non-linear patterns. Examining the limitations of existing studies, potential biases, and synthesizing overarching themes reveals a need for comprehensive and context-specific approaches. This study aims to address these gaps by focusing on GDP per capita concerning Pakistan, and also utilizes the latest datasets hence, contributing valuable insights to the ongoing discourse.

2.2. Favorable Environmental Impact of Renewable Energy

Fossil fuel dependence has led to a trade-off between financial expansion and environmental deterioration, particularly in emerging countries (Xue et al., 2021). A study conducted in Bangladesh, India, and Pakistan explored that, the use of clean energy decreases pressure on natural settings, while fossil fuel consumption exacerbates the pressure on natural capital (Xue et al., 2021). In a South and Southeast Asian countries study CS-ARDL (cross-sectional augmented autoregressive distributed lag) results for the period of 1990-2015 revealed that an amplified consumption of renewable energy significantly reduces ecological footprint (Sharma et al., 2021). In a broader analysis covering 152 economies during the period 1990–2017, Naqvi et al., 2020 quantified the negative and significant association between decreasing footprints and increasing consumption of renewables. Examining BRICS countries in 1992-2016, Danish et al., 2020 employed DOLS and FMOLS, and findings showed that clean energy sources can decrease ecological footprint. Similarly, a study focusing on China and Brazil within the BRICS context from 1971 to 2016, utilizing The Fourier ADL cointegration test, showed a significant reduction in environmental pressure with increased renewable energy generation (Pata, 2021). Results from an investigation into BRICS-T countries from 1990 to 2018 demonstrated a decrease in ecological footprint concurrent with increased renewable energy utilization (M. Usman & Makhdum, 2021). A comprehensive 130-country study for the period of 1992-to 2019, divided sample countries into three groups based on income levels, used threshold regression technique for panel estimations, resulted that growing use of green energy sources help to alleviate environmental pressure (Li et al., 2023). Saqib et al., 2023 conducted a study on emerging economies from 1990 to 2019, employing advanced panel estimation methods, and established that green energy significantly diminishes natural pressure from the natural capital. In the United States, utilizing quarterly data from 1st quarter of 1985 to the 4th quarter of 2014, O. Usman et al., 2020 exposed that, clean energy employs a declining pressure on ecological footprint in the longer period, while in the shorter period, clean energy is positively associated to ecological footprint. Contrasting findings emerged from an Indian study covering the period 1990 to 2016, which used the ARDL model and revealed that renewable energy harms ecological footprints in the long term (Roy, 2024). However, a study of 36 OECD countries from 1995 to 2018 found that the development of clean energy sources plays an important role in mitigating the pressure of energy use in natural settings (Q. Wang et al., 2023). A study for the period of 1990-2019 focused on the top 10 leading economies concerning ecological footprints revealed that green energy distribution has a growing effect on sustainable growth (Saqib et al., 2024). In a study encompassing G20 countries from 1990-2021, outcomes indicated that, in a longer time, renewable energy is negatively significant to the ecological footprints (Raza et al., 2023). A study in Croatia, Turkey, Poland, Czechia, and Romania from 1994-2018 reported a unidirectional causality running from green technologies to natural capital in Turkey (Tiwari et al., 2023). In a broader context, a study encompassing G7 and E7 nations from 1990 to 2020, utilizing the System GMM and panel Quantile regression, revealed that clean energy negatively influences the ecological footprint in the regions (Z. Wang et al., 2023).

2.3. Environmental influence of total population and education.

Demographic sprawl, recognized as a significant driver of climate change has brought global attention to the subject matter (Qi et al., 2020). This phenomenon is associated with increased hazardous emissions due to heightened energy consumption for commercial purposes (Y. Wang et al., 2016; Zhang & Lin, 2012). Research in 14 MENA countries from 1996 to 2012 revealed that population dynamics along with monetary features, increase ecological footprint (Al-Mulali & Ozturk, 2015) demographic features are also detrimental to the environment when taking carbon emissions as a measure of environmental degradation, a study in 23 European countries from 1990 to 2013 demonstrated (Al-Mulali et al., 2015). Contrary findings exist, with studies reporting a beneficial relationship between demographic determinants and climate change. For example, a study in Sri Lanka employing the bounds-testing technique revealed that demographics are negatively significant to CO2 releases (Gasimli et al., 2019). In 11 Asian countries from 1980 to

Journal of Green Knowledge and Sustainable Development (JGKSD)

J. Grn. Knw. & Sus. Dev., Volume 1, Issue 1 (2024)

2014, urbanization was associated with reduced SO_2 emissions (Munir & Ameer, 2018). Examined results from 1992-2012, for fifty-five middle-income nations revealed a negatively significant impact on hazardous gas releases in the long run as well as in the short run (Lv & Xu, 2019). However, a panel data analysis of 126 economies from 1971 to 2020 yielded mixed results regarding the climatic impacts of demographics (Iqbal et al., 2021). Increased population can heighten climate change impacts (Maji, 2017). A study in Pakistan from 1972 to 2020 using ARDL results revealed that population growth deteriorates the climate (Yousaf et al., 2022) Similarly, in China from 2003 to 2016, higher levels of population were associated with greater carbon emissions (Qi et al., 2020). A study in Thailand from 1974 to 2016, resulted in a negative association between demographics and ecological pressure in the longer period (Kongbuamai et al., 2020). Notably, the traditional physical planning efforts may not be sufficient for effective climate action, prompting the need for increased climate awareness through education. Initiatives like World Environment Day, established in 1972, reflect the importance of keeping people informed about climate change as an urgent global concern. A survey study in the United States highlighted the significant influence of media coverage, political mobilization, and advocacy groups on public concerns about the environment (Brulle et al., 2012). However, the lack of education on environmental damages not only hampers achievable environmental targets but also diminishes the quality of life in a country (Korhonen* & Lappalainen, 2004). A study in Indonesia revealed that respondents fully educated about environmental threats recommended ceasing mining activities to sustain the ecosystem (Kalalo, 2019). Moreover, higher education levels have been associated with an adverse influence on environemnt (Eyuboglu & Uzar, 2021). In conclusion, the literature consistently underscores the detrimental impact of population growth on the environment. However, it also suggests that educating the population can bring about positive change. Therefore, the current study assumes that education can play a vital role in decreasing the pressure exerted by the population on natural capital.

The reviewed literature provides insights into the connection between income, population, education, renewable energy, and ecological footprints across countries and regions. However, certain limitations hinder a comprehensive understanding. A notable drawback is the focus on specific nations, limiting the broader global perspective. Furthermore, the lack of a deep dive into contextual factors poses a challenge, and methodological variations make it challenging to compare results directly. Despite these challenges, an overarching trend suggests that increasing trends of highlighted dynamics tend to decrease and increase ecological footprints. Recognizing regional differences, there is a call for tailored approaches. While advanced econometric models show progress, addressing biases such as country-specific and timeframe limitations is essential for more reliable and globally applicable findings. However, methodological diversity, reflected in varying econometric models, impedes direct comparisons between studies. The existing literature includes regional bias, concentration on specific areas, and temporal bias stemming from inadequate reflection of recent developments. Data limitations and potential publication bias further contribute to a less comprehensive understanding of the relationship between the variables of concern. Hence the current study addresses these gaps and biases, the current study scrutinizes the impact of per-person real income, population, education, and renewable energy on ecological footprints in Pakistan by incorporating diverse regions and adopting standardized methodologies. Based on the discussed literature and identified gaps the study structures the theoretic structure as the Figure 6.

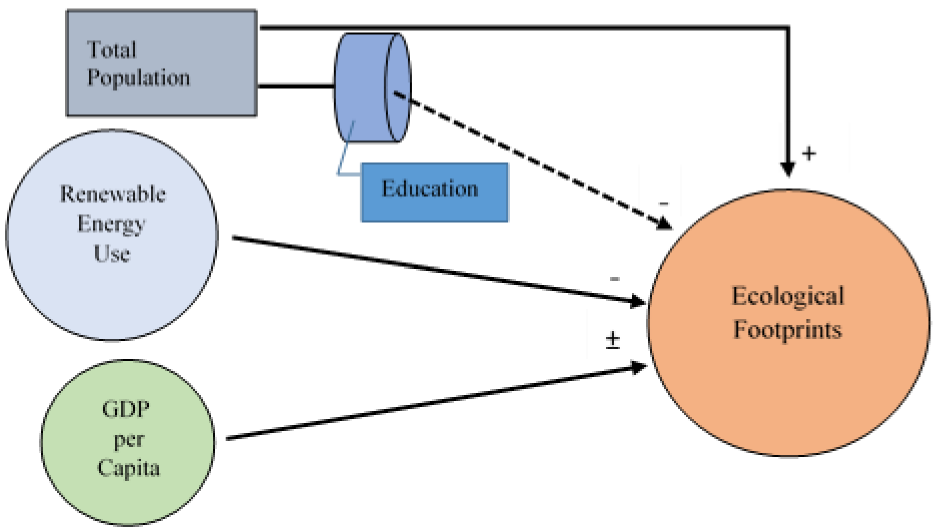

Figure 6. Framework of Study [Theorized by Authors]

3. Analytical Strategy

A time series dataset for Pakistan covering the period 1995-2020 has been compiled, incorporating variables; GDP per capita (lnGDP), Total Population (lnTP), Renewable Energy Use (lnRE), and Education Expenditures (lnGXE). Given the diverse sources from which the data originates and the use of different units of measurement, a natural logarithm transformation has been applied to standardize the datasets, denoted by the inclusion of the 'ln' symbol for each variable. Additionally, to assess the moderating impact of education, Education Expenditures have been multiplied by the Total Population to create an interaction term (see Table 1). The analytical approach involves initially examining the variables for unit root, specifically the Augmented Dickey-Fuller (Arltová & Fedorová, 2016; DeJong et al., 1992) and Phillips-Perron (Arltová & Fedorová, 2016; Perron, 1990) tests are conducted to ascertain the stationarity of the data. The investigation then extends to exploring the long-run relationships of the measures of concern through bounds testing. Significance in bounds testing guides the subsequent estimation of long-run and short-run relationships, accomplished using the Autoregressive Distributed Lag (ARDL) method for error correction (Arltová & Fedorová, 2016;

Journal of Green Knowledge and Sustainable Development (JGKSD)

J. Grn. Knw. & Sus. Dev., Volume 1, Issue 1 (2024)

Morley, 2006). This comprehensive empirical strategy aims to unveil the dynamics and associations within the dataset.

Table 1. List of Variables

Variables	Symbol	Measure	Data Sources
Dependent variables			
Ecological Footprints	lnEFP	Total global hectare	Global Footprint Network
Independent variables			
Income	lnIN	GDP per capita constant of 2015 in USD	WDI 2023
Total Population	lnTP	Total number of citizens on de facto definition of population	WDI 2023
Renewable Energy	lnRE	Percent of total final energy consumption	WDI 2023
Moderator Variable			
Government expenditure on education	lnGXE	Percent of government expenditure.	WDI 2023
The interaction term			
Total Population × Government Expenditure on Education	TED	Total Educated Population	Created By Authors

4. Empirical Findings

4.1. Outcomes of Unitroot and Cointegration Tests

Before proceeding with long-run estimations, it is crucial to address data stationarity, a pivotal step in statistical estimation that involves identifying the unit root in each variable. Unit root tests play a key role in estimating the integration order of the variables, aiding in the selection of the appropriate econometric model for the study (Mansoor Ahmed Golo; Han Dongping; Muhammad Hafeez; Isra Mahnaz, 2023). Overlooking this step could lead to misguided model selection, resulting in biased outcomes (Dongping et al., 2023; Golo, Han, Ibrar, & Din, 2023). The results of the ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) unit root tests are demonstrated in Tables 2 and 3, respectively, indicating that some measures are static at the level, while others are at the first difference. Consequently, the decision is made to accept data stationarity at both orders of integration as the variables of concern exhibit stationarity in mixed orders. Once the integration orders are confirmed, the following phase involves testing for a long-run association. A co-integration test is employed for this purpose (Le & Ozturk, 2020). In this regard, the findings of the bounds test for cointegration in Table 4 reveal an F-statistic of 6.798, significant at less than one percent because the upper bound value of 1% is 4.37. In conclusion, the unit root tests indicate a mixed order of integration, and the bounds testing confirms a long-run association among the variables.

Journal of Green Knowledge and Sustainable Development (JGKSD)

J. Grn. Knw. & Sus. Dev., Volume 1, Issue 1 (2024)

Table 2. Results of ADF Test

t-Stat.	I(0) Exogenous			I(1) Exogenous			Decision
	None	Constant	CT	None	Constant	CT	
lnEFP	1.753	-1.712	-2.595	-4.745*	-5.229*	-5.349*	1st Difference
lnIN	1.779	-0.976	-5.953*	-1.724***	-4.092*	-3.447***	Level
lnTP	1.830	-4.174*	-2.116	-2.724*	-2.586	-5.270*	Level
lnRE	-0.988	-1.798	-3.014	-3.727*	-3.709*	-3.731**	1st Difference
lnGXE	-0.026	-2.058	-2.051	-5.004*	-4.897*	-3.900**	1st Difference
TED	0.090	-1.925	-2.007	-4.992*	-4.896*	-3.888**	1st Difference

Note: *, **, *** show significance at 1%, 5% and 10%, respectively. CT: Exogenous Constant and Linear Trend., [ADF conditions: *MacKinnon (1996), Lag length automatic selection at Akaike info criterion (AIC)].

Table 3. Results of the PP Test

Adj. t-Stat.	I(0) Exogenous			I(1) Exogenous			Decision
	None	Constant	CT	None	Constant	CT	
lnEFP	3.115	-2.181	-2.407	-4.742*	-6.208*	-8.435*	1st Difference
lnIN	2.947	0.066	-2.381	-1.816***	-2.074	-1.837	1st Difference
lnTP	9.420	-8.481*	-1.433	-1.832**	-1.402	-1.678	Level
lnRE	-0.988	-1.743	-1.812	-3.742*	-3.730*	-3.749**	1st Difference
lnGXE	-0.021	-2.332	-2.221	-5.003*	-4.898*	-4.891*	1st Difference
TED	0.098	-2.264	-2.193	-4.993*	-4.997*	-4.900*	1st Difference

Note: *, **, *** show significance at 1%, 5% and 10%, respectively. CT: Exogenous Constant and Linear Trend., [PP conditions: Bandwidth selection: Newey-west automatic, and Spectral Estimation method is Bartlett Kernel.]

Table 4. Results of Co-integration Test

H_0: No long-run relationships exist
AIC-based ARDL model

Test Statistic		Significance	Critical Values	
F-statistic	Regressors (K)		I(0)	I(1)
6.798*	5	10%	2.20	3.09
		5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Note: * shows significance at 1%.

4.2. Long and Short Period Findings

Table 5 illustrates the shorter-period results of the ARDL model. The findings indicate that a one percent rise in per capita real income corresponds to a 1.726% upsurge in ecological footprints. This implies that a rise in income in the short run puts additional pressure on natural capital, leading to the deterioration of nature's serviceability. Conversely, in the longer period, real GDP per person decreases this pressure, as evidenced by the numerical outcome indicating that a one-unit increase in income reduces ecological footprints by 0.909, given the negative coefficient. These long-run findings align with the outcomes of research led by Sharma et al., 2021 in Asian countries, the outcomes are different from the study of Uddin et al., 2017, reflecting temporal disparities and variations in the sample composition of the underlined previous study. Promoting renewable energy in Pakistan is crucial for decreasing ecological footprints, as evidenced by the values of -1.516 in the shorter timespan and -1.878 in the long term, suggesting a significant negative impact of renewables on ecological footprints in the country. These results line up with similar studies conducted by Chien et al., 2023; Naqvi et al., 2020; Salah Uddin et al., n.d.; Sharma et al., 2021; M. Usman & Makhdum, 2021. Furthermore, the total population increases ecological footprints in the short as well as in the long run in Pakistan, with the numerical values indicating that a one-unit rise in total population raises ecological footprints by 16.415 and 0.479 in the short run and long run, respectively. Fortunately, education can play a vital role in moderating this influence. When the population has interacted with government expenditure on education, the result of the interaction term shows a decreasing impact of an educated population on ecological footprints. Specifically, a one percent rise in the education level of the population can decrease ecological footprints by 0.011 and 0.004 in the short run and long run, respectively, given the negative signs of both values, implying a favorable impact. Based on the empirical findings of this study we recommend policymakers prioritize the import of renewable technologies for the energy sector, as clean energy consumption proves significantly favorable for a greener future in Pakistan. Additionally, inculcating environmental concerns in the citizens of Pakistan through education can serve as a game-changer toward achieving a more sustainable and ecologically friendly future for the country.

Table 5. Longrun and Shortrun Estimations

AIC-based ARDL model (2, 2, 3, 2, 1)					
Dependent Variable: lnEFP					
Longrun Statisctics	**C**	**lnIN**	**lnTP**	**lnRE**	**lnTED**
Coefficient	23.985*	-0.909*	0.479**	-1.878*	-0.004***
t-Statistics	4.998	-3.742	3.275	-5.570	-2.281
Probability	0.001	0.005	0.011	0.000	0.052
Shortrun Statistics	**C**	**lnIN**	**lnTP**	**lnRE**	**lnTED**
Coefficient	41.293*	1.726**	16.415**	-1.516**	-0.011**
t-Statistics	4.545	2.335	2.752	-2.945	-3.307
Probability	0.001	0.048	0.025	0.019	0.011

Note: *, **, *** show significance at 1%, 5%, and 10%, respectively, Lag length automatic selection at Akaike info criterion (AIC).

4.3. Robustness Tests

The study conducts Ramsey RESET, Breusch-Godfrey Serial Correlation LM as well as Heteroskedasticity Tests for diagnosing the robustness of the model. The outcome of robustness tests is illustrated in Table 6, and the results reveal that the model is stable in all the cases. The findings reveal that the null hypotheses suggest “no serial correlation” and “no Heteroskedasticity” are accepted. Since the model is stable and there is no evidence of Heteroskedasticity and serial correlation, therefore findings of this study are robust.

Table 6 Diagnostic Results

Ramsey RESET Test., H_0: Model has no omitted variables			
	Value	df	Probability
t-statistic	0.051	7	0.961
F-statistic	0.003	(1, 7)	0.961
Likelihood ratio	0.008	1	0.927
Heteroskedasticity Test: Breusch-Pagan-Godfrey.,			
H_0: Homoskedasticity			
F-Statistics	0.583		
Probability	0.820		
Chi-Square	0.637		
Breusch-Godfrey Serial Correlation LM Test			
H_0: No serial correlation at up to 2 lags			
F-Statistics	2.603		
Probability	0.154		
Chi-Square	0.005		

5. Conclusion

This study delves into a comprehensive analysis of the time series dataset for Pakistan spanning 1995-2020, encompassing variables; GDP per capita, Total Population, Renewable Energy Use, and Education Expenditures. The transformation of data through natural logarithms has been instrumental in standardizing units, and the introduction of an interaction term involving Education Expenditures and Total Population provides a moderating impact of education on the population. The analytical strategy, including unit root tests, bounds testing, and the ARDL model, is meticulously employed to unravel the intricate dynamics and associations within the dataset. Unit root tests ascertain a mixed order of integration, acknowledging the diverse nature of the variables’ stationarity. Subsequent bounds testing confirms a long-run association among the variables. The short-run results of the ARDL model reveal that an increase in GDP per capita leads to an increase in ecological footprints, signifying the immediate pressure on natural capital. However, in the long run, GDP per capita inversely correlates with ecological footprints, aligning with the findings of Sharma et al. (2021) in Asian countries but differing from Uddin et al. (2017), possibly due to temporal disparities and sample variations. The promotion of renewable energy emerges as a crucial factor in reducing ecological footprints, as evidenced by significant negative impacts in both the short and long run. Moreover, the study highlights that an increase in total population contributes to heightened ecological footprints in both temporal dimensions. However, education emerges as a mitigating factor, as an increase in education levels, particularly when interacting with government expenditure, shows a favorable impact on reducing ecological footprints. The model employed in the current study has undergone stability tests, demonstrating its robustness. There is no evidence of heteroskedasticity or serial correlation, affirming the reliability of the findings.

6. Recommendations

Policymakers in Pakistan are presented with key recommendations derived from the empirical findings. Firstly, prioritizing the import and implementation of renewable technologies for the energy sector is paramount. The significantly favorable impact of clean energy consumption underscores the potential for a more sustainable and environmentally friendly future. Additionally, recognizing the mitigating role of education in reducing ecological footprints, policymakers should invest in educational initiatives. Promoting environmental awareness through education can lead to a positive shift in the ecological behavior of the population. Integrated policy approaches that consider the interplay between economic factors, population dynamics, renewable energy adoption, and education are essential for achieving a harmonious balance between economic development and environmental sustainability. Periodic assessments and updates of policies are recommended to ensure their ongoing effectiveness.

7. Limitations of the Study

Despite the valuable insights gained from this study, several limitations should be acknowledged. The reliance on available time series data from 1995-2020 introduces constraints related to data quality and availability, potentially impacting the robustness of the findings. Omitted variables and unexplored factors may exist, influencing the relationships under investigation. The study's temporal scope may limit its applicability to certain policy periods, and cross-country variability poses challenges in generalizing findings to other nations.

8. Future Research Directions

To address these limitations and contribute to a more robust body of knowledge, future research should prioritize enhanced data collection, incorporating a broader range of variables and ensuring data reliability. Longitudinal studies will provide a more dynamic understanding of relationships over time. Context-specific analyses and qualitative research, such as stakeholder interviews or case studies, can offer deeper insights into the social and institutional dynamics influencing ecological outcomes. Future studies could focus on assessing the actual impact of implemented policies related to renewable energy promotion, education, and population management. Additionally, integrating climate-related variables into the analysis can contribute to a more comprehensive understanding of the environmental impact, especially considering the influence of climate change on ecological footprints. By addressing these limitations and pursuing these future recommendations, research in this domain can evolve to better inform sustainable policymaking and contribute to global efforts for environmental conservation and economic development.

Declarations

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Originality statement

Authors confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

Ethical Approval

Not applicable because the study is conducted on publically available data that was approved by all the authors.

Consent to Publish

All authors have approved the manuscript and agree to publish it in the Journal of Green Knowledge and Sustainable Development.

Data availability statement

The datasets used and analyzed in the current study are publicly available on the Climate Change Knowledge Portal and the World Development Indicators of the World Bank's official website. However, the authors can provide the data in a useful format upon request.

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