SWAYS OF ENVIRONMENTAL DEGRADATION ON ECONOMIC GROWTH OF PAKISTAN: A TIME SERIES ANALYSIS

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Sways of Environmental Degradation on Economic Growth of Pakistan: A Time Series Analysis

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ABSTRACT

The study focuses on the three sources of pollution, specifically air, water and land pollution, and estimates the relationship between environmental degradation and economic growth through the instruments of environmental Kuznets curve over the years 1995 till 2022. Further, to justify environment-economy nexus, an empirical analysis is conducted to determine the extent of the impact of air, water and land pollution, as well as monetary, physical and human capital on economic growth of Pakistan. Indices covering economic, demographic and environmental variables are constructed by using techniques of principal component analysis and principal factor analysis. The results of augmented Dicky-Fuller test show that all series are stationary at first difference of lag length one with-intercept and without trend. The ARDL bound test supports the presence of long-run co-integration. The magnitude and sign of long-run and short-run ARDL coefficients are consistent with the economic growth and environmental theory. The linear, positively sloped environmental Kuznets curve truly represents the early stages of economic growth and development in Pakistan. The negative significant value of the error correction term is an optimistic conclusion that the short-run shocks can be corrected to long-run equilibrium in all types of environmental degradation and economic growth model. The composition of the indices of environmental degradation provides the determinants of different types of pollutions that can be controlled by monitoring these determinants. At the policy level to identify and to mitigate the air, water and soil pollution, the ministry of climate change and environmental coordination should seek international assistance and play a role in tracking and monitoring the performance of SDG-related determinants of pollution.

Keywords: environmental degradation, economic growth, environmental Kuznet curve, principal component analysis, principal factor analysis, ARDL.

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LIST OF ABBREVIATIONS

Abbreviations	Definitions
ACF	Weighted Average of Access to Clean Fuels and Technologies for Cooking as a Percentage of Total Population.
ADF	Augmented Dicky-Fuller.
ADR	Weighted Average of Age Dependency Ratio Percentage of Working Age Population.
AME	Agricultural Methane Emission as a Percentage of Total Emissions.
ANE	Agricultural Nitrous Oxide Emission as a Percentage of Total Emissions.
ARDL	Autoregressive Distributed Lag.
BSS	People Using at Least Basic Sanitation Services as a Percentage of Population.
CFW	Total Contributing Family Workers as a Percentage of Total Employment.
CH4	Methane.
CIN	Weighted Average of Changes in Inventories.
CLA	Weighted Average of Permanent Cropland as a Percentage of Land Area.
CO	Carbon Monoxide.
COE	Co_2 Emissions Metric Tons per Capita.
CO_2	Carbon Dioxide.
CPT	Weighted Average of Container Port Traffic.
E	Index of Environmental Degradation.
EA	Air Pollution.
EAS	Employment in Agriculture as a Percentage of Total Employment.
ECT	Error-Correction Term.
EKC	Environmental Kuznet Curve.

EPA	Environmental Protection Agencies.
ET	Land Pollution.
EW	Water Pollution.
FCN	Fertilizer Consumption, Kilograms per Hectare of Arable Land
FDI	Foreign Direct Investment.
FDI	Net Inflows of Foreign Direct Investment as a Percentage of GDP.
FUE	Fertilizer-Use-Efficiency.
FWR	Renewable Internal Freshwater Resources Per Capita.
GCF	Gross Capital Formation as a Percentage of GDP.
GDS	Gross Domestic Savings
GDS	Gross Domestic Savings as a Percentage of GDP.
GEX	Government Expenditure on Education as a Percentage of Total Government Expenditure.
GHE	Domestic General Government Health Expenditure Per Capita.
GVA	Gross Value Added.
HAC	Heteroscedasticity and Autocorrelation Consistent.
HFC	Hydrofluorocarbons.
KM	Monetary Capital.
KP	Physical Capital.
L	Index of Human Capital.
LEP	Labor Force Participation Rate as a Percentage of Total Population Ages 15^+.
MET	Methane Emissions Kiloton Of CO_2 Equivalent.
MHT	Medium And High-Tech Industry as a Percentage of Manufacturing Value Added.
MKC	Market Capitaluzation of Listed Domestic Companies as a Percentage of GDP.
MKC	Market Capitalization of Listed Domestic Companies
NDC	Net Domestic Credit.
NEECA	National Energy Efficiency and Conservation Authority.
NFA	Net Foreign Assets.

NFI	Bentler-Bonnet Normed Fit Index.
NIA	Net Investment in Nonfinancial Assets as a Percentage of GDP.
NO_2	Nitrogen Dioxide.
NOE	Nitrous Oxide Emissions in Energy Sector as a Percentage of Total Emissions.
ODA	Net Official Development Add Received.
ODA	Net Official Development Add Received as a Percentage of Gross Capital Formation.
ODE	People Practicing Open Defectation as a Percentage of Population.
OGC	Electricity Production from Oil, Gas and Coal Sources as a Percentage of Total Electricity Production.
OGG	Other Greenhouse Gas Emissions, Hydrofluorocarbon, Perfluorocarbons and Sulfur Hexafluoride.
OMX	Ores and Metals Exports as a Percentage of Merchandise Exports.
PCA	Principal Component Analysis.
PDN	Population Density i.e., People Per Square km of Land Area.
PEQ	Portfolio Equity Net Inflows.
PFA	Principal Factor Analysis.
PFC	Perfluorocarbons.
POD	Probability of Dying among Youth Ages 20 to 24 Years Per 1000.
PRR	Personal Remittances Received as a Percentage of GDP.
RAD	Research and Development Expenditure as a Percentage of GDP.
RCG	Technical Cooperation Grants.
RFI	Relative Fit Index.
RMSR	Root Mean Squares Residual.
SF6	Sulfur Hexafluoride.
SFM	Total Self Employed as a Percentage of Total Employment.
SIC	Schwarz Information Criterion.
SMW	People Using Safely Managed Drinking Water Services as a Percentage of Total Population.

TCG	Technical Coorperation Grants.
TED	Educational Attainment at-least Completed Short-Cycle Tertiary Education for Population Ages 25^+ as a Percentage of Total Population.
URP	Urban Population as a Percentage of Total Population.
WDI	World Development Indicators.

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DEDICATION

Dedicated to my Parents

&

Supervisor

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

All living creatures including human being reliant on the quality of the environment for their survival. The environment consists of atmosphere, land surface, land below water, forests, mountains and supplementary natural resources. Environmental degradation is the corrosion or deterioration of these natural resources. The continuous use of these natural resources lead to the deterioration of natural habitat, disturbances in ecosystem, extinction of species, and diminution of water, soil, and air that explode environmental degradation.

Environmental degradation is a global threat faced by inhabitants of earth right now. The industrial revolution that sows the seed of industry beside enlargement in transportation sector has increased the harmful emission manifolds due to usage of fossil fuel and depletion of forests. The higher concentration of gasses, like carbon monoxide and carbon dioxide raise the temperature, melt glaciers at higher speed and create the global water shortage. In short, the pursuit of realizing economic growth, global economies are unable to avoid the predictable environmental degradation in the form of massive degradation and depletion of the natural resources, scarcity of fuel wood, air, water and land contamination, soil erosion, extermination of species, air smog in metropolitan localities and generating environmentally detrimental emissions that leads to global warming.

Historically, Pakistan was an agrarian country but in chasing the traditional route of economic growth and development through industrialization, Pakistan is facing the issues of natural resource depletion and environmental degradation. As an outcome of industrialization, the disgusting spectacle of air pollution, water logging, air, water and land contamination, land degradation and desertification are on rise. These incongruous environmental affects in conjunction with rapid population growth have augmented the poverty. Notably, the rural population in Pakistan is using traditional energy sources to meet demand for energy that deteriorate environmental quality through carbon dioxide emission as well. In short, a complex interplay of ecological-economics tradeoff between environmental degradation and economic growth is a key issue in developing economies like Pakistan. So, present study is imperative to assess the sways of environmental degradation on economic growth of Pakistan.

1.2 Significance of the Study

The phenomenal cause of environmental pollution are developing economies that are in transition stages of rapid economic growth. Pakistan's blue and brown environmental problems include motor vehicle emissions, urban and industrial air pollution, industrial waste water and land pllution, contamination of domestic waste groundwater, and marine and coastal zone pollution. Green environmental problems affect irrigated agriculture, rainfed agriculture, forests, and rangelands through the problem of waterlogging, salinity and solidicity of soil, deforestation and rangeland degradation. An economic concern here is neither to compromise the environmental degradation nor the economic growth. In this respect different quantitative approaches and theoretical frameworks appraising relationship between economic growth and ecosystem (including, air, land and water) degradation are developed. As a need of time, present study specifically focusses on the determinants of environmental degradation besides carbon emission that is a big move beyond carbon as traditional variable of only air pollution. Further, present study is significant in a sense that it aims to empirically test the environmental Kuznets curve hypothesis for Pakistan to determine the relationship between indicators of environmental degradation and economic growth. This analysis is helpful to understand the presumed dilemma between economic development and environmental protections specifically, a tradeoff that exist between two feisty goals. In short, present study open the way for harmony between the two goals (economic development and environmental protection), where environmental friendly economic growth is core global unprejudiced.

1.3 Research Questions and Objectives of the Study

A generalized preference for eco-friendly growth and awareness to environmental problems promotes a higher level of ecosystem conservation. On these lines the research questions in present study are:

First Question: what factors are responsible for air pollution, water pollution and land pollution?

Second Question: beside physical capital and human capital how economic growth is affected by environmental degradation? and

Third Question: does environmental Kuznet curve (EKC) hypothesis holds for Pakistan or not?

The first question broadens our analysis of EKC through a specific focus on environmental degradation factors besides carbon emission that is a big move beyond traditional variable of only air pollution. The main contribution of present study is based on the second and the third questions that are related with environment-economy nexus. To justify this nexus an empirical analysis is conducted to determine the magnitude of the effect of air pollution, the water pollution and the land pollution, besides physical capital and human capital on economic growth of Pakistan. Finally, the present study is an attempt to comprehensively assess the validity of EKC hypothesis for Pakistan over the years 1995 till 2022. Thus, the main objectives of present study are:

Objective-1: to determine the factors responsible for the air pollution, the water pollution and the land pollution;

Objective-2: by using an amended version of Solow growth model, determine the impact of environmental degradation on economic growth of Pakistan; and

Objective-3: to test the validity of EKC hypothesis separately for each type of pollution (specifically, air, water and land pollution).

1.4 Limitations of the Study

In achieving above mentioned objectives following minor limitations do exist. First, due to time constraint only single country (Pakistan) is considered in present analysis, but a vast cross-sectional on regional alliance of countries e.g., SAARC countries or sub Saharan countries etc., can augment the literature very well. Second, data constraint limits our analysis for the years 1995 through 2022 only. Third, in present study the exercise of determining the factors affecting three types of pollution provide a mere snapshot in time based on the insights of one particular country without spillover effect. As, the selection of single country lacks the incentives to control the boundary-less environmental degradation as air above earth is not restricted to only Pakistan's boundary instead it covers the whole globe of earth. In short, emissions discharged in Pakistan affects the complete ozone layer not only the sky above Pakistan.

1.5 Organization of the Study

To achieve the above-mentioned objectives the thesis is divided into seven chapters. The existing empirical literature on environmental Kuznet curve (EKC) and on impact of environmental degradation on economic growth is reviewed in Chapter 2. The Chapter 3 provides theoretical foundations of EKC hypothesis. An endogenous growth model is constructed in chapter 3 as well. The models to prove EKC hypothesis are also presented in chapter 3. In Chapter 4 data sources and analytical frame work for construction of indices is mentioned. The estimation procedure to be used in empirical analysis is also explained in chapter 4. The construction of indices is presented in Chapter 5. The empirical results with discussion are provided in Chapter 6. Finally, in Chapter 7, conclusions with policy recommendations are provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In present chapter the review of theoretical and empirical literature for relationship between economic growth and three types of environmental pollution (namely; air, land and water pollution) is provided. Basically, environmental Kuznet curve (EKC) is credited to Simon Kuznets (1955) and is practically applied by Grossman and Krueger (1991). The EKC curve shows that human activities responsible for economic growth explode the environmental degradation. Chapter 2 is divided into five sections. After introduction, empirical literature for EKC on the basis of air pollution is summarized in section 2.2. In section 2.3 empirical literatures for EKC on basis of water pollution is justified. In section 2.4 empirical literatures for EKC on basis of land pollution is mentioned. Finally, in section 2.5, chapter 2 is being concluded.

2.2 Empirical Literature on Environmental Kuznets Curve and Air Pollution

The ecological movement in industrialized economies that started in the 1960s blames economic development as the main cause of pollution. The human activities result in environmental degradation through the emission of greenhouse gases (i.e., main cause of air pollution). The environmental Kuznet curve (EKC) gives us the dimensions of interaction between economic growth and environmental pollution. The subsection 2.2.1 elucidates determinants of air pollution present in existing empirical literature and the subsection 2.2.2 provides literature on impact of air pollution on economic growth.

2.2.1 Empirical Literature on Determinants of Air Pollution

The present subsection provides the main determinants of air pollution indicated by the empirical literature. Khan et al., (2020) investigated the association between energy consumption and CO_2 emission, and economic growth in Pakistan by using annual time series data from the year 1965 through 2015. The results of ARDL bound test for co-integration indicated that the long-run energy consumption has a positive impact on CO_2 emission in Pakistan. Both the short-run and long-run coefficients of economic growth has positive effect on the CO_2 emission in Pakistan. Based on the estimation results Khan et al., recommended that policy maker in Pakistan replace renewable energy sources with old traditional sources of coal, oil and gas, and hence reduce the CO_2 emission to guarantee the sustainable economic development of Pakistan.

There is a common trend of using solid fuels for cooking over open fires that ignites the human health related, environmental and socio-economic problems. Dickinson et al., (2015) assessed stove use and cooking behavior, cooking emanations, personal exposure and household air pollution, health problem, and air quality in the Kassena-Nankana district in Northern Ghana. The data was collected from 200 household and contained information about each stove in the sampled households related to type (traditional and improved) of stoves, types of fuel used in stove, usage of stove in term of days, and dishes cooked on each stove. The electronic SUMs were used to measure stove temperature after every five minutes. The G-Pods were installed throughout the sampled region to measure the variability of air pollution and to identify the sources of pollutant. The G-Pods were designed to measure O_3, CO, NO, and NO_2 using Alpha-sense B4 electrochemical sensors. The Ozone, CO, and NO_2 were also assessed using MO_x sensors. The meteorological data was collected through climatronics sonic anemometer, and through temperature and humidity sensor. The sampled pollutant source encompassed emissions from commercial cooking, trash burning and from vehicle emissions. The emission estimates of this study can be further utilized as inputs in the weather research forecasting model and to simulate the interactions between regional weather.

Jalil and Mahmud (2009) studied the long-run relationship between carbon emissions and income, energy consumption, and foreign trade for China by using time series data from the year 1975 through 2005. The ARDL methodology is used for testing the EKC hypothesis. The results of Granger causality tests indicated one-way causality from economic growth to CO_2 emissions. A quadratic relationship between income and CO_2 emission for the sample period supported inverted U-shaped EKC relationship. The results of this study indicated that the CO_2 emissions were significantly determined by income and energy consumption, but trade has a positive and statistically insignificant impact on CO_2 emissions.

2.2.2 Empirical Literature on Effects of Air Pollution on Economic Growth

The detrimental impact of air pollution on economic growth demands more attention to the tolerable level of environmental harm after which EKC hypothesis holds. The decomposition analysis of "growth-environment relationship" is effective to understand the causes of GHG emissions and diminution effects of environmental pollution that lead to appropriate environmental policies.

Tenaw (2021) empirically tested the "structural effects of growth" on carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions in Ethiopia over the year 1975 through 2017. Both in the short-run and long-run the ARDL results confirmed that the "scale effect of growth" increases all types of GHG emissions (CO_2, CH_4, and N_2O). whereas the "composition effect" has a long-run monotonically increasing relationship with CO_2 emissions and a non-increasing pattern with CH_4 and N_2O emissions. Technically, a "growth effect" existed for CO_2 emissions and an Inverted-U shaped EKC existed for CH_4 and N_2O emissions. As Toda-Yamamoto Granger causality test indicated a unidirectional causality from the three structural components of growth to GHG emissions, Tenaw suggested that a self-correcting mechanism in the growth process is unable to reduce environmental pollution.

Yusuf et al., (2020) explored the relationship between greenhouse gas emissions, output growth and energy consumption among African OPEC countries (namely; Algeria, Angola, Equatorial Guinea, Gabon, Libya and Nigeria) using the panel ARDL model for the period 1970 through 2016. They examined the relationship between greenhouse gasses (specifically, carbon dioxide, methane and nitrous oxide) and economic growth. In the long-run the study showed a positive impact of economic growth on both CO_2 and CH_4 emissions but the impact of growth on nitrous oxide emission was though positive yet was statistically insignificant. In the short-run the economic growth had a significant positive effect on CH_4 emissions; however, its effect on CO_2 and nitrous oxide emissions was positive but statistically insignificant.

Their empirical results showed a non-linear relationship between methane emissions and economic growth ratifying the inverted U-shaped EKC for CH_4 emission.

Işık et al., (2019) depicted the effect of real GDP, population, fossil energy and renewable energy consumptions on CO_2 emission in ten US states. The panel estimation technique with cross-sectional dependence is applied to the data from 1980 through 2015. The results confirmed the validity of inverted U-shaped EKC for Florida, Illinois, Michigan, New York, and Ohio. Their results indicated a negative impact of fossil energy consumption on CO_2 emission in Texas (an oil-producing State) and positive influence of energy consumption on CO_2 emissions in Florida (a Sunshine State).

Zaidi and Fehri (2019) investigated the relationship between CO_2 emission and GDP growth for Sub-Saharan countries for the period 2000 through 2012. Their empirical findings showed a two-way causality between energy consumption and economic growth. Though the results also supported a two-way causal relationship between energy consumption and electricity consumption, yet pollution had negatively affected the electricity consumption, therefore the rise in economic growth increased the level of CO_2 emission and vice versa.

Davis (2012) stated that air pollution was generated by contaminating factories to trucks and traffic on roads. He identified the impact of economic activity on haze (COH), carbon monoxide (CO), and nitrogen dioxide (NO_2) in California from the years 1980 through 2000. He concluded that economic output and air pollution-generating activities are large, at high economic growth augmented by low unemployment, leading to more air pollution. The opposite scenarios hold during a recession. He also analyzed the impact of economic contraction and reduced industrial activity on pollution and found that over the period of analysis in California, economic recessions were correlated with less pollution.

2.3 Empirical Literature on Environmental Kuznets Curve and Water Pollution

The clean water is crucial to human health, quality of life, environmental safety, economic activity, and sustainable development. The subsection 2.3.1 expounds determinants of water pollution present in empirical literature and the subsection 2.3.2 offers literature on impact of water pollution on the economic growth.

2.3.1 Empirical Literature on Determinants of Water Pollution

Water covers 71-percent of the earth's surface and hence is essential for the life on earth. According to CIA the world fact book report "only 2.5-percent of the earth's water is fresh water, and 98.8-percent of this is held as ice and groundwater. Less than 0.3percent of fresh water is contained in rivers, lakes and the atmosphere, while 0.003-percent of it is in biological bodies and in manufactured products". The quality of fresh water in ground and surface is of great concern and factors affecting water quality in developing countries are complex with regard to surface water pollution. In this section empirical literature on the topic is reviewed to provide a summary of the main sources of water pollution.

Templeton et al., (2015) declared pit latrines as an onsite sanitation facility in developing countries. They professed that the nitrate pollution arising from pit latrines is distressing in the areas with a near-surface aquifer. The researchers visited three densely populated, peri-urban areas near three West African cities (namely, Abidjan, Abomey-Calavi, and Dakar,) for data about the latrines in use and for the nature of soil and groundwater underneath. The results highlighted the likelihood of nitrate pollution exceeding the WHO value in drinking water of 50 mg/L after a period of two years for the aquifer situated 5 meters below the pits. On the basis of empirical results, the researchers suggested that a careful siting of latrines away from high water table areas, more frequent pit emptying or switching to urine diversion toilets may be effective solutions to reduce nitrate passage from pit latrines into ground water.

Khatri and Tyagi (2014) identified that the quality of ground and surface water in rural and urban areas is affected by natural processes and anthropogenic influences. They assisted that "the natural processes is responsible for the scarcity of water leading to weathering of rocks, evapotranspiration, depositions due to wind, leaching from soil, run-off due to hydrological factors, and biological processes in the aquatic environment". They further added that the natural processes also cause changes in the pH and alkalinity of the water, its phosphorus loading, and in fluoride and sulphates contents. According to the researcher "the anthropogenic factors affecting water quality include use of fertilizers, manures and pesticides, activities of animal husbandry, inefficient irrigation practices, deforestation of woods, pollutants from industrial effluents and domestic sewage, mining, and from recreational activities". According to researchers these anthropogenic influences cause high concentrations of heavy metals, mercury, coliforms and nutrient loads in water.

2.3.2 Empirical Literature on Impacts of Water Pollution on Economic Growth

The contaminated and polluted water poses a severe threat to the human life, the environment and to the economy as a whole. With industrial development the lakes and rivers become polluted. Both economic development and protection of the lake and rivers is a matter of great concern to researchers therefore in present subsection a relationship between economic development and water pollutants are being reviewed.

Sheikh and Hassan (2020) attempted to test EKC hypothesis for river water pollution for 15 districts of Uttar Pradesh in India. A panel unit root tests, Pedroni co-integration test and FMOLS method was employed to investigate pollution-income relationship for two water pollutants (namely, biochemical oxygen demand and total coliform). Findings revealed no evidence of EKC for biochemcial oxygen demand, but the results validate the existence of an EKC for total coliform. The researcher suggests that government policies that purposes for elimination of open defecation and for increase in toilet access in rural India may reduce total coliform levels in India.

Choi et al., (2015) professed that through the process of industrialization and eventual diversification in South Korea the economic growth is complemented by environmental degradation, and increasingly polluted rivers and reservoirs. To assess the relationship between economic growth and water quality indicators for South Korea, Choi et al., considered four rivers. A positive change in environmental and industrial policy improved water quality and bought the growth of overall national economy of South Korea. However, individual analysis of rivers showed heterogeneous results. The relationship between biochemical oxygen demand and GDP for Geum and Nakdong rivers and for Yeongsan and Nakdong rivers support the EKC hypothesis. An issue indicated by study is that industrial restrictions aimed at improving environmental quality at one location encouraged polluters to relocate industry elsewhere. Choi et al., found that economic growth is unable to automatically solve and remedy the pollution problems. So policy makers keep them aware of generating pollution havens, and deliberately track the environmental quality improvements rather than waiting for economic growth to automatically bring about such perfections.

Paudel et al., (2005) used disaggregated data to test the validity of EKC hypothesis for three major water pollutants namely; phosphorus, nitrogen and dissolved oxygen in Louisiana. They used a "fixed-effects parametric specification" for quadratic and cubic functional forms and a "flexible semiparametric specification" to investigate the EKC hypothesis for water pollution using watershed level data. They admitted that semiparametric approach is more flexible as it smoothly approximated nonlinearities in the relationship between environmental quality and income. The parametric model indicated the turning points within the range of $6636-$13877, $10241-$12993, and $6467-$12758 for phosphorus, nitrogen and dissolved oxygen, respectively. However, the EKC was found to be valid only for nitrogen. The estimation results of a fixed effects model demanded an effective environmental policy for pollution control associated with economic growth.

2.4 Empirical Literature on Environmental Kuznets Curve and Land Pollution

In addition to health impacts, land pollution hampers economic growth and development by reducing the utilization of land for agriculture, and for forestry. Only limited studies have focused on land specific environmental degradation namely; deforestation, tree cutting and agricultural land abandonment. The subsection 2.4.1 comprehend the determinants of land pollution present in existing empirical literature, and subsection 2.4.2 reviews the literature on impact of land pollution on economic growth.

2.4.1 Empirical Literature on the Determinants of Land Pollution

The land pollution refers to the deterioration of the earth's crust through the accumulation of solid and liquid waste materials that pollute ground and soil. Zhang and Wang (2020) exposed the heavy metal pollution caused by natural and human activities. The "natural causes" included the redistribution of soil wreckage and the hydraulic migration of soil parent rock due to wind. The "human factors" included abandoned mining, intensive application of fertilizer and pesticide, and contaminated water irrigation. Zhang and Wang defined heavy metal pollution as "a process involving metal elements that changes with time and space under the interaction of biological system forces and environmental system forces". The researchers suggested that the analysis of the determinants of heavy metals in soil deals with pollution and reduce the damage by toxic soil.

Bai et al., (2020) confessed the fertilizer-use-efficiency (FUE) as an effective means to minimize use of fertilizer and to reduce land contamination. They assessed the FUE of agricultural production for a panel data of 31-provinces in China from the year 2007 till 2017 using a "stochastic-frontier-method". They used geographical-weighted-regression model to examine the spatial impact of non-agricultural employment ratio, educational level, disaster ratio, and farmers' income on FUE and revealed a "spatial dispersion" and "agglomeration effect" for different provinces. The results showed that the average FUE in China was 0.747 with significantly decreasing trend. The FUE had a significant regional difference and spatial positive correlation in different provinces. The non-agricultural employment ratio was leading factor for increasing FUE for all provinces. The farmers' income had a significant negative impact on FUE indicating that EKC plays an important role in improving FUE. The influence of educational level on FUE was positive but insignificant. Finally, the disaster ratio had a positive impact on FUE.

Chandhani et al., (2019) gauged the effects of chemical fertilizers on ecosystem of India. They acknowledged that though the chemical fertilizer increases the plant growth and helps to achieve the food security yet the plants grown through fertilizer not poses good plant characters. The chemically produced plants transfer the toxic chemicals in the human body. The harmful effect of the chemical fertilizers arose from their production and from their by-products specifically from production of toxic gases namely; NH_4, CO_2, and CH_4 etc., that are sources of air pollution. If the chemical wastes from the industries are disposed-off into water, they accumulate in water through the process of water eutrophication. If chemical fertilizers are continuously added in soil they contaminate the soil and hence soil pollution. In short, fertilizer used as an input in crop production depletes the environment and ecosystem by draining the natural resources and by threatening the life on earth. Chandhni et al., suggested that the antagonistic effects of synthetic chemicals on environment and human health can be reduced by use of organic inputs such as manure, bio-fertilizers, bio-pesticides, and nano-fertilizers, that improve the fertilizer-use-efficiency. Chandhni et al., suggested organic farming for healthy natural environment and ecosystem.

2.4.2 Empirical Literature on Effects of Land Pollution on Economic Growth

The ground below our feet is composed of soil, silt, and rocks, so every square meter of it is idiosyncratic in terms of its structure, its composition, and the life that it comprises and supports. In short, soil pollution is a global threat. Therefore, this subsection reviews the literature on the sways of land pollution on economic growth.

Ajanaku and Collin (2020) recognized deforestation as contributing loss of biodiversity, degradation of land, erosion of soil and climate change. They asserted that in the past fifty years, the continent of Africa had gigantic loss of forests due to change in economic structure, increase in population and globalization. Ajanaku and Collin tested the validity of EKC hypothesis from the year 1972 through 2014. They measured net deforestation as a change in arable land and expounded its determinants namely, institutions, bio-energy consumption, and demographic factors. To establish long-run and short-run equilibrium relationships among these variables they used a pooled mean group estimator for ARDL model. Their empirical findings confirm the EKC hypothesis for net deforestation in Africa with a turning point at US$ 1303.

Persistent deforestation is a terrific global environmental issue. Cuaresma et al., (2017) explored a link between overexploitation of natural resources (including forests) and economic development. In order to study the deforestation across different countries they used satellite data on forest cover along national borders.

After controlling for trans-border geo-climactic differences, they found income per capita as the robust determinant of differences in cross-border forest cover. They showed that the marginal effect of per capita income growth on forest cover is strong at the earliest stages of economic development, and declines in advanced economies, presenting strongest evidence for the existence of an EKC hypothesis.

A refit of ruined soil is a vital global concern. Lal (2010) declared soil erosion as a global issue because of its adverse environmental and economic impacts. Economic impacts on productivity assessed by Lal were on-site and off-site direct effects on crops. Lal used (i). agronomic (soil) quality evaluation, (ii). economic assessment, and (iii). knowledge surveys to assess on-site effects of erosion on agronomic productivity. To access the erosion-induced changes in soil quality in relation to productivity, he established field plots on the same soil with different severity of past erosional phases. The impact of past erosion on productivity was assessed by relating plant growth to the depth of a root-restrictive horizon. Whereas the impact of current erosion on productivity was assessed by using paired watersheds, and that of future erosion was measured by using top-soil removal-and-addition technique. He assessed on-site impact of erosion in relation to soil life, soil loss tolerance, soil resilience or ease of restoration, and soil management options for ecological use of soil and water resources. Lal concluded that soils is managed effectively to control soil erosion then air and water quality may be improved beside increase in food production. The researcher also proclaimed that the risk of global annual loss of food production due soil erosion are subject to weather conditions during the growing season, soil management, farming systems, and soil ameliorative input used. Lal also recorded that the erosion-caused losses of food production were most severe in Asia, Sub-Saharan Africa, and in tropic region. The literature review of above subsections is summarized in Appendix-A.

2.5 Literature Gaps

The theoretical literature describes the determinants of pollution and helps to construct indices for air, water and land pollution separately. However, most empirical studies use carbon dioxide emissions as the sole cause of air pollution. Similarly, for environmental Kuznet curve only carbon dioxide is used, whereas literature gap for water and land pollution exist. A notable innovation in the present study is the simultaneous consideration of all three sources of pollution to account for the relationship between environmental degradation and economic growth via the instruments of Cobb-Douglas production function and environmental Kuznets curve.

CHAPTER 3

THEORETICAL FRAMEWORK AND METHODOLOGY

3.1 Introduction

The present chapter is divided into four sections. In section 3.2 the theoretical foundations for the study are highlighted, in section 3.3 models for empirical analysis are constructed and in final section 3.4 concluding remarks are recounted.

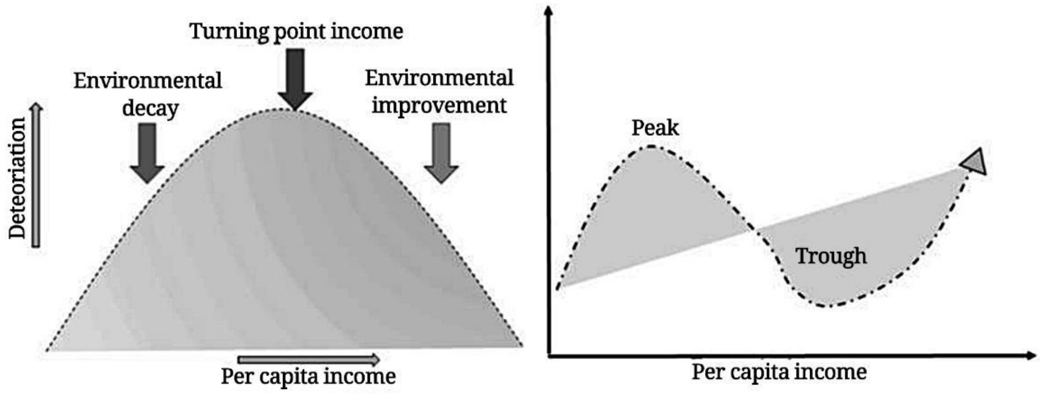
3.2 Theoretical Framework

The Environmental Kuznets Curve (EKC) hypothesis was articulated to untangle the global environment-economy nexus from the dynamics of growth and development (Dasgupta et al., 2002; Cole, 2007; and Galeotti, 2007). The EKC hypothesis, which shows a non-linear inverted U-shaped relationship between ecosystem degradation and a national income and has captivated attention of scholars and policy-makers for environment friendly policymaking. This inverted U-shaped relationship was first presented by Simon Kuznets (1955) to examine the causes of long-run changes in per capita distribution of income in the progression to economic growth. The empirical work on EKC started in the 1990s after the United Nations Conference on “Environment and Development”, also known as “Earth Summit”, held on June 3-14, 1992 in Rio de Janeiro, Brazil, to globally address the crucial problems of environmental protection and socio-economic development.

Since the 1990s, EKC is adopted in the empirical analysis of environmental economic literature by prominent researchers, namely Grossman and Kruger (1991, 1995), Lucas, et al., (1992), Selden and Song (1994), Tucker (1995), Jalil and Mahmud (2009), Harbaugh et al., (2000) and Mosconi et al., (2020) who identified different specifications for EKC by incorporating a linear income descriptor representing a decoupling baseline, and linear and squared income terms presenting usual U-shaped EKC (Mazzanti et al., 2008), and higher level cubic or polynomial income terms that are extensions of the U-shaped EKC toward more explicit N-shaped relationships (Sobhee, 2004) used for policymaking purpose.

Figure 3.1

A Classical Inverted U-shaped EKC (left) and a More Complex N-shaped EKC Curve (right)



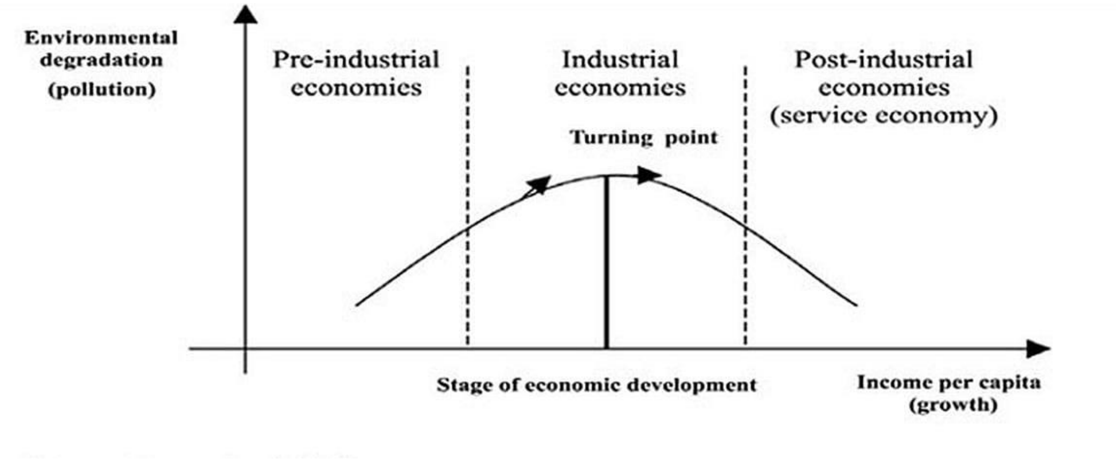
Source: Sobhee (2004)

The environment-economy relationship mentioned in above paragraph is further supported by Figure 3.1, and is either a linear (de-coupling hypothesis) or polynomial (re-linking hypothesis). In the former case, Rasli et al., (2018) stated that "economic growth has beneficial effects on environmental quality over the whole range of incomes". In the latter case Chelleri et al., (2015) stated that "if economic growth shows beneficial effects on environmental quality at lower (or intermediate) income levels, a re-linking process is expected at higher income levels". Galeotti et al., (2006) related a country's income with improving environmental conditions at the lower and intermediate levels and more stable conditions at the higher ones.

Ahmed and Long (2012) related the inverted u-shaped EKC with global trends that with increase in economic activity, initially environmental condition of developing countries deteriorates as an increase in pollution and dirt contaminate atmosphere, water and at ground but once the transition economy attain certain income level and economic growth rate the environment starts getting cleaner due to environmental restoration. Where environmental restoration is achieved through increased environmental awareness, improved production technology, transition to green technology, enactment and enforcement of environmental protection laws and regulations, and willingness to pay for environmental remediation.

Figure 3.2

Environmental Kuznets Curve explaining the Stages of Economic Development



Source: Panayotou (1993)

A hypothetical inverted-U shaped EKC is presented in Figure 3.2. According to Hwa, et al., (2016) the shape of EKC varies for different countries depending upon the pace of development of these countries.

3.3 Methodology

Present section is divided into two subsections. In subsection 3.3.1 endogenous growth model for determination of the impact of environmental degradation on economic growth of Pakistan is elucidated. In subsection 3.3.2 the model to substantiate the environmental Kuznets curve hypothesis is provided.

3.3.1 Econometric Model for Sways of Environmental Degradation on Economic Growth

In this section the empirical model is fabricated that is used to determine the empirical relationship between environmental degradation and economic growth beside capital and labor. For a long time, economic growth was considered as a product of capital accumulation and of exogenous technological progress. Later on, a proponent of endogenous growth theory, Romer (1987) claimed certain endogenous factors responsible to explain observed differences in growth rate of various countries. Among these factors, environment is very important. Here a modified form of Cobb-Douglas production function by Paul Douglas and Charles Cobb (1928) is presented as:

$$Y_t = A_t K_t^{\alpha} E_t^{\beta} L_t^{1-\alpha-\beta} e^{\varepsilon} \quad ..... 3.1$$

where Y_t is measurement of economic growth, A_t is constant level of technology, K_t is an index of capital, L_t is an index of human capital presenting labor, E_t is an index of environmental degradation, and ε_t is stochastic error term with zero mean and constant variance. Here $\alpha > 0$, $\beta > 0$, and $(1-\alpha-\beta) < 1$ to satisfy the assumption of constant returns to scale. Now take natural logarithm on both sides:

$$ln\, Y_t = \, lnA_t + \alpha\, lnK_t + \beta lnE_t + (1-\alpha-\beta) lnL_t + \varepsilon_t\, ln\, e \quad ..... 3.2$$

where $lnA_t = c, (1-\alpha-\beta) = \gamma$ and $ln\, e = 1$, therefore econometric estimate-able specification of equation 3.2 is given as:

$$ln\, Y_t = \, c + \alpha\, lnK_t + \beta\, lnE_t + \gamma\, lnL_t + \, \varepsilon_t \quad ..... 3.3$$

where lnY_t is a measurement of economic growth i.e., GDP per capita annual percentage growth and K_t is the index of capital. Let us split the index of capital into two components namely, intangible monetary capital (KM_t) and tangible non-monetary i.e., physical capital (KP_t). The E_t is the index of environmental degradation having components of air pollution (EA_t), water pollution (EW_t), and land pollution (ET_t). The L_t is the index of human capital presented by the traditional variable of labor. By substituting components of K_t ($i.e., KM_t$ and KP_t) and E_t ($i.e., EA_t, EW_t$ and ET_t) in equation 3.3, the modified equation is given as:

$$ln\, Y_t = \, c + \theta_1\, lnKM_t + \theta_2\, lnKP_t + \, \theta_3\, lnEA_t + \, \theta_4\, lnEW_t + \theta_5\, lnET_t + \theta_6\, lnL_t + \, \varepsilon_t \quad ..... 3.4$$

where "c" is intercept "θs" are elasticities and "t" denotes time period. According to economic theory of production capital and labor are expected to be positively associated to GDP per capita annual percentage growth and environmental degradation is expected to be negatively related to GDP per capita annual percentage growth in equation 3.4. To test the impact of environmental degradation on economic growth of Pakistan, the intangible monetary capital (KM_t) is a weighted average of net inflows of foreign direct investment as a percentage of GDP (FDI_t), gross domestic savings as a percentage of GDP (GDS_t), market capitaluzation of listed domestic companies as a percentage of GDP (MKC_t), net domestic credit (NDC_t), net foreign assets (NFA_t), net official development add received as a percentage of gross capital formation (ODA_t), personal remittances received as a percentage of GDP (PRR_t), portfolio equity net inflows (PEQ_t) and technical cooperation grants (RCG_t) as is presented in index 3.4(a). Whereas the tangible non-monetary or physical capital (KP_t) is a weighted average of changes in inventories (CIN_t), gross capital formation as a percentage of GDP (GCF_t), gross value added (GVA_t), medium and high-tech industry (including construction) as a percentage of manufacturing value added (MHT_t), net investment in nonfinancial assets as a percentage of GDP (NIA_t) and the research and development expenditure as a percentage of GDP (RAD_t) as is presented in index 3.4(b).

$$KM_t = \omega_{11}\,FDI_t + \omega_{12}\,GDS_t + \omega_{13}\,MKC_t + \omega_{14}\,NDC_t + \omega_{15}\,NFA_t + \omega_{16}\,ODA_t + \omega_{17}\,PRR_t + \omega_{18}\,PEQ_t + \omega_{19}TCG_t \qquad \text{... 3.4 (a)}$$

and

$$KP_t = \omega_{21}\,CIN_t + \omega_{22}\,GCF_t + \omega_{23}\,GVA_t + \omega_{24}\,MHT_t + \omega_{25}NIA_t + \omega_{26}RAD_t \qquad \text{... 3.4 (b)}$$

The index of environmental degradation through air pollution (EA_t) is a weighted average of access to clean fuels and technologies for cooking as a percentage of total population (ACF_t), CO_2 emissions metric tons per capita (COE_t), electricity production from oil, gas and coal sources as a percentage of total electricity production (OGC_t), methane emissions kiloton of CO_2 equivalent (MET_t), nitrous oxide emissions in energy sector as a percentage of total emissions (NOE_t), and other greenhouse gas emissions, hydrofluorocarbons (HFC) perfluorocarbons (PFC) and sulfur hexafluoride (SF6) thousand metric tons of CO_2 equivalent (OGG_t).

The index of environmental degradation through water pollution (EW_t) is a weighted average of container port traffic (CPT_t), people using at least basic sanitation services as a percentage of population (BSS_t), people using safely managed drinking water services as a percentage of total population (SMW_t) and renewable internal freshwater resources per capita (FWR_t), Whereas the index of environmental degradation through land pollution (ET_t) is a weighted average of permanent cropland as a percentage of land area (CLA_t), agricultural methane emission as a percentage of total emissions (AME_t), agricultural nitrous oxide emission as a percentage of total emissions (ANE_t), employment in agriculture as a percentage of total employment (EAS_t), fertilizer consumption, kilograms per hectare of arable land (FCN_t), ores and metals exports as a percentage of merchandise exports (OMX_t), people practicing open defectation as a percentage of population (ODE_t), population density i.e., people per square km of land area (PDN_t) and urban population as a percentage of total population (URP_t).

$$\mathrm{EA_t} = \omega_{31}\,\mathrm{ACF_t} + \omega_{32}\,\mathrm{C0E_t} + \omega_{33}\,\mathrm{OGC_t} + \omega_{34}\,\mathrm{MET_t} + \omega_{35}\,\mathrm{NOE}_t + \omega_{36}\,\mathrm{OGG_t} \quad \text{... 3.4 (c)}$$

$$\mathrm{EW_t} = \omega_{41}\,\mathrm{CPT}_t + \omega_{42}\,\mathrm{BSS_t} + \omega_{43}\,\mathrm{SMW_t} + \omega_{44}\,\mathrm{FWR_t} \quad \text{... 3.4 (d)}$$

and

$$\mathrm{ET_t} = \omega_{51}\,CLA_t + \omega_{52}AME_t + \omega_{53}\,ANE_t + \omega_{54}\,EAS_t + \omega_{55}\,FCN_t + \omega_{56}OMX_t + \omega_{57}\,\mathrm{ODE}_t + \omega_{58}\,PDN_t + \omega_{59}\,URP_t \quad \text{... 3.4 (e)}$$

The L_t is the index of human capital, presenting labor. The L_t is a weighted average of age dependency ratio percentage of working age population (ADR_t), total contributing family workers as a percentage of total employment (CFW_t), domestic general government health expenditure per capita (GHE_t), educational attainment at least completed short-cycle tertiary education for population ages 25+ as a percentage of total population (TED_t), government expenditure on education as a percentage of total government expenditure (GEX_t), labor force participation rate as a percentage of total population ages 15+ (LFP_t), probability of dying among youth ages 20 to 24 years per one-thousand (POD_t) and total self employed as a percentage of total employment (SFM_t).

$$L_t = \omega_{61}\,ADR_t + \omega_{62}CFW_t + \omega_{63}\,GHE_t + \omega_{64}\,TED_t + \omega_{65}\,GEX_t + \omega_{66}LFP_t + \omega_{67}POD_t + \omega_{68}SFM_t \quad \text{.... 3.4 (f)}$$

The main equation 3.4 determines the impact of environmental degradation, beside capital and labor, on economic growth of Pakistan. And the indices 3.4(c), 3.4(d) and 3.4(e) elucidate the factors responsible for environmental degradation specifically air pollution, water pollution and land pollution.

3.3.2 Environmental Kuznets Curve Hypothesis

To test the validity of a quadratic (inverted u-shaped) or cubic (N-shaped) environmental Kuznets curve i.e., to empirically test the relationship between environmental degradation (one at a time) and economic growth, following specifications of equation 3.4 are used:

$$ln\,EA_t = \varphi_{10} + \varphi_{11}\,lnY_t + \varphi_{12}\,lnY_t^2 + \varphi_{13}\,lnY_t^3 + \varphi_{14}\,lnKM_t + \varphi_{15}lnKP_t + \varphi_{16}lnEW_t + \varphi_{17}\,lnET_t + \varphi_{18}\,lnL_t + \varepsilon_{1t} \quad \text{..... 3.5 (a)}$$

$$ln\,EW_t = \varphi_{20} + \varphi_{21}\,lnY_t + \varphi_{22}\,lnY_t^2 + \varphi_{23}\,lnY_t^3 + \varphi_{24}\,lnKM_t + \varphi_{25}lnKP_t + \varphi_{26}lnEA_t + \varphi_{27}\,lnET_t + \varphi_{28}\,lnL_t + \varepsilon_{2t} \quad \text{..... 3.5 (b)}$$

and

$$ln\,ET_t = \varphi_{30} + \varphi_{31}\,lnY_t + \varphi_{32}\,lnY_t^2 + \varphi_{33}\,lnY_t^3 + \varphi_{34}\,lnKM_t + \varphi_{35}lnKP_t + \varphi_{36}lnEA_t + \varphi_{37}\,lnEW_t + \varphi_{38}\,lnL_t + \varepsilon_{3t} \quad \text{..... 3.5 (c)}$$

Following Twerefou et al., (2017) three potential outcomes are expected to exist in the above empirical models of environmental degradation (i.e., models of air, water and land pollution).

First: when φ_{11}, φ_{21} and $\varphi_{31} > 0$, φ_{12}, φ_{22} and $\varphi_{32} = 0$, and φ_{13}, φ_{23} and $\varphi_{33} = 0$, there exists a linear relationship between environmental degradation and economic growth, suggesting that an increase in growth rate leads to an increase in environmental degradation (air, water and land pollution) mainly in developing countries and transition economies.

Second: when φ_{11}, φ_{21} and $\varphi_{31} > 0$, φ_{12}, φ_{22} and $\varphi_{32} < 0$, and φ_{13}, φ_{23} and $\varphi_{33} = 0$, there exists an inverted U-shaped relationship between environmental degradation and economic growth. The signs of $\varphi_{12}, \varphi_{22}$ and φ_{32} are negative showing that environment friendly policies lead environmental improvement instead of degradation.

Third: when φ_{11}, φ_{21} and $\varphi_{31} > 0$, φ_{12}, φ_{22} and $\varphi_{32} < 0$, and φ_{13}, φ_{23} and $\varphi_{33} > 0$. The expected signs of $\varphi_{13}, \varphi_{23}$ and φ_{33} are again positive, having N-shaped EKC, displaying extensive use of resources that leads to their depletion and deformation. For example, extensive digging of land not only depletes it yet also deforms it.

In above equations the expected signs for intangible monetary capital (KM_t), tangible non-monetary i.e., physical capital (KP_t) and human capital are mixed because in case of developed countries the value of $\varphi_{14}, \varphi_{15}, \varphi_{18}, \varphi_{24}, \varphi_{25}, \varphi_{28}, \varphi_{34}, \varphi_{35}$ and φ_{38} are mostly expected to be negative, but are expected to be positive in case of developing countries and transition economies. The negative signs indicate environmental improvement whereas positive signs show environmental degradation.

3.4 Conclusions

An environment friendly economic growth is fundamental global objective so present study through testing the validity of environmental Kuznets curve hypothesis is helpful to understand the alleged dilemma between economic development and environmental protection, specifically a tradeoff that exist between these variables.

CHAPTER 4

DATA SOURCES AND ANALYTICAL FRAMEWORK

The present chapter explains the data sources and estimation techniques for research. For this purpose, chapter is divided into four sections. The section 4.1 provides sources for secondary time series data from the year 1995 through 2022 to explore the sways of environmental degradation on economic growth of Pakistan. The section 4.2 explains procedure to construct indices with the help of principal component analysis and principal factor analysis. The section 4.3 explains test that justify the existence of co-integration analysis and section 4.4 provide a relationship between economic growth and environmental degradation. Finally, the section 4.5 concludes the chapter.

4.1 The Data Sources

The study uses extensive data on a large number of variables including economic, demographic and environmental variables. All the variables used in the construction of indices are defined and constructed according to definitions provided by World Bank for World Development Indicators (WDI, 2022). Summary of data required for present analysis is provided in Table 4.1.

Table 4.1

Variables with Definitions and Data Sources

S.No	VARIABLES /INDICES	INDICATORS USED IN CONSTRUCTION OF INDICES	DATA SOURCES
1.	economic growth (Y_t)	Proxy by GDP per capita annual percentage growth	WDI
2.	monetary capital (KM_t)	weighted average of net inflows of foreign direct investment as a percentage of GDP, gross domestic savings as a percentage of GDP, market capitalization of listed domestic companies as a percentage of GDP, net domestic credit, net foreign assets, net official development add received as a percentage of gross capital formation, personal remittances received as a percentage of GDP, portfolio equity net inflows, and technical cooperation grants.	WDI
3.	non-monetary or physical capital (KP_t)	weighted average of changes in inventories, gross capital formation as a percentage of GDP, gross value added, medium and high-tech industry (including construction) as a percentage of manufacturing value added, net investment in nonfinancial assets as a percentage of GDP and the research and development expenditure as a percentage of GDP.	WDI
4.	air pollution (EA_t)	weighted average of access to clean fuels and technologies for cooking as a percentage of total population, CO_2 emissions metric tons per capita, electricity production from oil, gas and coal sources as a percentage of total electricity production, methane emissions kiloton of CO_2 equivalent, nitrous oxide emissions in energy sector as a percentage of total emissions, and other greenhouse gas emissions, HFC, PFC and SF6 thousand metric tons of CO_2 equivalent.	WDI
5.	water pollution (EW_t)	weighted average of container port traffic, people using at least basic sanitation services as a percentage of population, people using safely managed drinking water services as a percentage of total population and renewable internal freshwater resources per capita.	WDI
6.	land pollution (ET_t)	weighted average of permanent cropland as a percentage of land area, agricultural methane emissions as a percentage of total, agricultural nitrous oxide emissions as a percentage of total emissions, employment in agriculture as a percentage of total employment, fertilizer consumption kilograms per hectare of arable land, ores and metals exports as a percentage of merchandise exports, people practicing open defecation as a percentage of population, population density i.e., people per sq. km of land area, and urban population as a percentage of total population.	
7.	human capital (L_t)	weighted average of age dependency ratio percentage of working-age population, total contributing family workers as a percentage of total employment, domestic general government health expenditure per capita, educational attainment at least completed short-cycle tertiary education for population ages 25+ as a percentage of total population, government expenditure on education as a percentage of total government expenditure, labor force participation rate as a percentage of total population ages 15+, probability of dying among youth ages 20 to 24 years per one thousand and total self-employed as a percentage of total employment.	WDI

Source: Author.

4.2 Multivariate Techniques for Construction of Indices

The indices presented in equation 3.4(a) through 3.4(f) in Chapter 3, are constructed on the theoretical grounds. In present chapter these indices covering monetary, demographic and environmental variables are empirically constructed by using techniques of principal component analysis (PCA) and principal factor analysis (PFA). Where a non-parametric technique of principal component analysis (PCA) presented by Pearson (1901) and corroborated by Hotelling (1933, 1936) is suitable to sack up a large number of variables under a manageable number of heading known as indices (index of monetary capital, index of physical capital, index of human capital and the indices of environmental degradation in present study). Technically, PCA is a method that uses an orthogonal transformation to convert a set of possibly correlated variables into indices of linearly uncorrelated variables called PCs. Thus each PC is a linear combination of optimally weighted observed variables where linear combination coefficients (weights) or loadings, obtained through PFA, are used in interpreting the newly constructed components (indices).

4.2.1 Performing Principal Component Analysis

For the construction of monetary, demographic and environmental indices, following four-steps procedure is used.

Step 1: Standardization of Variables

As principal component analysis (PCA) is very sensitive to the variance of the initial variables. Therefore, a variable with a large range can dominate a variable with a small range. To circumvent this problem, the data are transformed to obtain comparable scales. Mathematically, standardizing a variable is accomplished by subtracting the mean value of the variable and dividing by the corresponding standard deviation of that variable.

Step 2: Pair-Wise Correlation Matrix

The correlation matrix is used to examine the degree of linear relationship between pairs of variables. Using a correlation matrix is equivalent to using a covariance matrix for standardized data, with scaled variables having zero mean and standard deviation of one. Correlation based PCA produces the exact similar results as the individual variances for each variable are equal to each other.

Step 3: Kaiser-Meyer-Olkin Feasibility Test for Principal Component Analysis

The data suitability for PCA can be tested on the basis of Kaiser Meyer Olkin Measure of Sampling Adequacy (MSA). The Kaiser′s MSA index ranges from 0 to 1. According to Kaiser and Rice (1974) the values of Kaiser′s "MSA above 0.90 are considered marvelous, the values in the 0.80s are meritorious, the values in the 0.70s are middling, the values in the 0.60s are mediocre, the values in the 0.50s are miserable and all others are unacceptable". The small values of Kaiser′s MSA indicate that PCA of variables is not good idea. A high value between 0.50 and 1.0 indicates that PCA is appropriate technique to be used.

Step 4: Kaiser-Guttman Unit Eigen-value Criterion for Appropriate Number of Principal Components

According to Preacher and MacCallum (2003) and Jackson (1993) the selection of number of components is the most important decision in PCA formation. In Kaiser-Guttman unit eigenvalue criterion the PCs with eigenvalue greater than one are preferred to be retained in column eigenvectors. Jackson (1993) tested the accuracy of the unit eigenvalue criterion and as a rule of thumb, he used the cumulative percentage of variance of eigenvalue extracted from successive components that exceeded 60 percent of total variance and consider it good enough for selection of number of these PCs.

4.2.2 Performing Principal Factor Analysis

In order for original loadings of factor coefficients (weights) of equations 3.5(a) through 3.5(f), exact scoring of the coefficients through un-rotated Bartlett weighted least squares (WLS) regression method is recommended (Bartlett, 1937). The method minimizes the estimated errors with respect to weights. Then following Grice (2001) the unique recode method is recorded to a non-zero value for the variable with the highest absolute value in a row. Also, the multiple correlation coefficients (i.e., multiple R) is used to measure the legitimacy of coefficients in each index.

The R-squared values for different indices show the percentage of variation in Bartlett WLS regression explained by the selected components. Another goodness of fit indicator i.e., root mean squares residual (RMSR) represents the square root of the average or mean of the covariance residuals, i.e., the difference between corresponding elements of the observed and predicted covariance matrix. The zero RMSR represents a perfect fit. According to Browne and Cudeck (1989) RMSR should be less than 0.08 and ideally less than 0.05.

For the construction of indices different criteria of goodness of fit are considered. Bentler-Bonnet Normed Fit index (NFI) and Relative Fit index (RFI) are used to compare the target model with original (null) model. A value of Bentler-Bonnet NFI varies from 0 to 1, where value of 1 is ideal. The Bentler-Bonnet NFI equals the difference between the chi-square statistics of null and of target model, divided by the chi-square statistics of the null model. If the Bentler-Bonnet NFI exceeds 0.90 (Byrne, 1994) or 0.95 (Schumacker and Lomax, 2004) then regression model is acceptable. A Bentler-Bonnet NFI of 0.90, for example indicates that the concerned model fit by 90 percent relative to null or independent model.

4.3 The Unit Root Test for Stationarity

The formal method to test the stationarity of multiple series is the unit root test. In present thesis an augmented Dicky-Fuller test is chosen to examine the stationarity of variables and indices at level and first difference.

The simple Dicky-Fuller unit root test is valid only for AR(1) process. For higher order lag AR(p), the Augmented Dicky-Fuller (ADF) applied by Mackinnon (1991, 1996) is modified for our indices of 3.4(a) through 3.4(f) at level and at first difference. The following equations 4.1 is a general form for first difference series Y_t, KM_t, KP_t, L_t, EA_t, EW_t, and ET_t. Where β_{i0} are constants (measuring drift), β_{i1} are the coefficient of a deterministic time trend, "p" is the lag order of autoregressive process and "ε_{it}" are pure white noise error terms. Imposing the restriction $\beta_{i0} = 0$, and $\beta_{i1} = 0$ corresponds to a dependent variable (at first difference) as a random walk without drift and without deterministic trend. Likewise, using the constraint $\beta_{i0} \neq 0$, and $\beta_{i1} = 0$ corresponds to modelling a dependent variable (at first difference) as a random walk with drift. By allowing lags of the order "p" (selected through Schwarz Information Criteria) the ADF formulation obtain unbiased estimate of "δ_i" where "$i = 1, 2, 3, \ldots\ldots, 7$" for seven series.

$$\Delta Y_t = \beta_{i0} + \beta_{i1} t + \delta_i Y_{t-1} + \sum_{j=1}^{p} \alpha_{jt} \Delta Y_{t-j} + \varepsilon_{it} \qquad \ldots\ldots 4.1$$

The unit root test is carried out under the null hypothesis $H_0\colon \delta_i = 0$, against the alternative hypothesis of $H_1\colon \delta_1 < 0$ by using t-ratio $t_{\propto} = \frac{\hat{\delta}}{se\,(\hat{\hat{\delta}})}$. The $\hat{\delta}_i$ is the estimate of δ_i and $se(\widehat{\delta_\iota})$ is standard error of $\widehat{\delta_\iota}$. If the calculated t-statistics is less than the critical t-value, then the null hypothesis that indices or variable has unit-root or non-stationary is rejected against no unit root or stationary series.

4.4 Autoregressive Distributional Lag Bound Test for Co-integration Analysis

After performing augmented Dicky-Fuller test for stationarity, ARDL Bound test introduced by Pesaran et al. (2001) is used to test the long-run relationship between indices and variables. The ARDL Bound test has many advantages over the classical co-integration approaches. First; the conventional co-integration techniques specifically, Johansen co-integration test and Engle- Granger co-integration test require all independent variables to be at a same level of integration (e.g., I(1) process). The ARDL method, on the other hand, does not require all variables to have the same integration process, it can be applied for variables that are I(1), I(0), or mutually co-integrated, but no variables is allowed to be I(2) to avoid the spurious results. Second; a conditional error correction term can be achieved by reducing a vector auto-regression framework through a simple linear transformation having both short-run and long-run dynamics. Third; the empirical results show that the ARDL approach provides consistency in the OLS estimators of the short-run parameters and the ARDL based estimators of the long-run coefficients even in the small sample sizes.

The ARDL Bound test for co-integration is a test on parameter significance using F-statistics. In present study it is used for a joint test that the coefficients of the error correction terms are not all zero. Then the computed F-statistics is compared with two asymptotic critical values corresponding to I(0) or I(1). If the F-statistics is below the lower critical value, one fails to reject the null hypothesis of no co-integration. In contrast, if the F-statistics is above the upper critical value, one rejects the null hypothesis and concludes that co-integration is possible. In case if the F-statistics fall between the lower and upper critical values, results of Bound test are inconclusive.

4.5 Autoregressive Distributional Lag Model with Conditional Error Correction Term

As a final step, autoregressive distributed lag (ARDL) approach is used to test the validity of environmental Kuznets curve (EKC) hypothesis i.e., to estimate the magnitude through which each capital, labor, output and different sources of environmental degradation affect the specific type of pollution (air, water or land pollution) one by one in equation 3.5(a) through equation 3.5(c). Actually, ARDL approach is used to analyze dynamic relationships of time series data in a single-equation framework. In present study all the three types of pollutions and GDP per capita annual percentage growth is allowed to regress on their own past realizations (i.e., the autoregressive part) as well as current and past values of additional explanatory variables (i.e., the distributed lag part). Following Chng (2019) and Ahmed (2012), corresponding to equations 3.4, 3.5(a), 3.5(b) and 3.5(c), the long-run intertemporal dynamic ARDL models with unrestricted constant and without trend are constructed as following:

$$\begin{aligned}\Delta ln\, Y_t = \alpha_{10} &+ \sum_{k=1}^{n} \alpha_{11k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{12k}\, \Delta \ln KM_{t-k} \\ &+ \sum_{k=0}^{n} \alpha_{13k}\, \Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{14k} \Delta lnEA_{t-k} \\ &+ \sum_{k=0}^{n} \alpha_{15k}\, \Delta \ln EW_{t-k} \qquad \text{... 4.2 (a)} \\ &+ \sum_{k=0}^{n} \alpha_{16k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{17k}\, \Delta \ln L_{t-k} \\ &+ \varphi_{11}\, lnY_{t-1} + \varphi_{12} lnKM_{t-1} + \varphi_{13} lnKP_{t-1} + \varphi_{14} lnEA_{t-1} \\ &+ \varphi_{15}\, lnEW_{t-1} + \varphi_{16}\, lnET_{t-1} + \varphi_{17}\, lnL_{t-1} + \varepsilon_{1t}\end{aligned}$$

$$\Delta ln\, EA_t = \alpha_{20} + \sum_{k=1}^{n} \alpha_{21k}\, \Delta \ln EA_{t-k} + \sum_{k=0}^{n} \alpha_{22k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{23k} \Delta lnY_{t-k}^{2} + \sum_{k=0}^{n} \alpha_{24k} \Delta lnY_{t-k}^{3} + \sum_{k=0}^{n} \alpha_{25k}\, \Delta \ln KM_{t-k} + \sum_{k=0}^{n} \alpha_{26k}\, \Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{27k} \Delta lnEW_{t-k} + \sum_{k=0}^{n} \alpha_{28k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{29k}\, \Delta \ln L_{t-k} + \varphi_{21} \ln EA_{t-1} + \varphi_{22}\, lnY_{t-1} + \varphi_{23}\, lnY_{t-1}^{2} + \varphi_{24}\, lnY_{t-1}^{3} + \varphi_{25}\, lnKM_{t-1} + \varphi_{26}\, lnKP_{t-1} + \varphi_{27}\, lnEW_{t-1} + \varphi_{28}\, lnET_{t-1} + \varphi_{29}\, lnL_{t-1} + \varepsilon_{2t} \quad \text{.... 4.2 (b)}$$

$$\Delta ln\, EW_t = \alpha_{30} + \sum_{k=1}^{n} \alpha_{31k}\, \Delta \ln EW_{t-k} + \sum_{k=0}^{n} \alpha_{32k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{33k} \Delta lnY_{t-k}^{2} + \sum_{k=0}^{n} \alpha_{34k} \Delta lnY_{t-k}^{3} + \sum_{k=0}^{n} \alpha_{35k}\, \Delta \ln KM_{t-k} + \sum_{k=0}^{n} \alpha_{36k}\, \Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{37k} \Delta lnEA_{t-k} + \sum_{k=0}^{n} \alpha_{38k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{39k}\, \Delta \ln L_{t-k} + \varphi_{31} \ln EW_{t-1} + \varphi_{32}\, lnY_{t-1} + \varphi_{33}\, lnY_{t-1}^{2} + \varphi_{34}\, lnY_{t-1}^{3} + \varphi_{35} lnKM_{t-1} + \varphi_{36}\, lnKP_{t-1} + \varphi_{37}\, lnEA_{t-1} + \varphi_{38}\, lnET_{t-1} + \varphi_{39}\, lnL_{t-1} + \varepsilon_{3t} \quad \text{.... 4.2 (c)}$$

and

$$\Delta ln\, ET_t = \alpha_{40} + \sum_{k=1}^{n} \alpha_{41k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{42k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{43k} \Delta lnY_{t-k}^{2} + \sum_{k=0}^{n} \alpha_{44k} \Delta lnY_{t-k}^{3} + \sum_{k=0}^{n} \alpha_{45k}\, \Delta \ln KM_{t-k} + \sum_{k=0}^{n} \alpha_{46k}\, \Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{47k} \Delta lnEA_{t-k} + \sum_{k=0}^{n} \alpha_{48k}\, \Delta \ln EW_{t-k} + \sum_{k=0}^{n} \alpha_{49k}\, \Delta \ln L_{t-k} + \varphi_{41} \ln EA_{t-1} + \varphi_{42}\, lnY_{t-1} + \varphi_{43}\, lnY_{t-1}^{2} + \varphi_{44}\, lnY_{t-1}^{3} + \varphi_{45} lnKM_{t-1} + \varphi_{46}\, lnKP_{t-1} + \varphi_{47}\, lnEA_{t-1} + \varphi_{48}\, lnEW_{t-1} + \varphi_{49}\, lnL_{t-1} + \varepsilon_{3t} \quad \text{.... 4.2 (d)}$$

In equations 4.2(a) through 4.2(d) the α_{ik} present the short-run error-correction dynamics, and φ_{ik} show the long-run dynamics. Where i = 1, 2, 3, 4 for GDP per capita annual growth rate and for three types of pollutions (namely; air, water and land pollution), and k is for lag length. The α_{i0} are constant terms, and ε_{it} are white noise error terms. The null hypothesis of ARDL bound testing for co-integration is

$H_0: \alpha_{i0} = \alpha_{i1} = \alpha_{i2} = \cdots = \alpha_{i9} = 0$, suggesting for no co-integration, and the alternative hypothesis is $H_1: \alpha_{i0} \neq \alpha_{i1} \neq \alpha_{i2} \neq \cdots \neq \alpha_{i9} \neq 0$. Pesaran et al. (2001) adapted two set of critical values identified as lower bound and upper bound. The lower bound is for indices and variables with I(0), whereas the upper bound considers indices and variables with I(1). The null hypothesis for no co-integration is not rejected when computed F-statistics is smaller than lower bound critical value. The null hypothesis for no co-integration can be rejected when the F-statistics is greater than upper bound critical value. If the F-statistics fall between lower and upper bound, then the result is inconclusive. Banarjee et al. (1998) established a long-run relationship for negative and statistically significant error-correction.

Supporting Banarjee et al. (1998), Saboori and Sulaiman (2013) substituted all lagged level variables with error-correction term, and then tested the coefficients for statistical significance. After establishing the existence of long-run relationship, error-correction model (ECT) is employed to estimate the short-run coefficients and that coefficient of error-correction term. The equations, 4.3(a), 4.3(b), 4.4(a), 4.4(b), 4.5(a), 4.5(b), 4.6(a) and 4.6(b) show the general formula of dynamic ARDL regression model with conditional error correction terms, and structure of error correction terms for economic growth model and three types of pollutions:

$$\begin{aligned}\Delta ln\, Y_t = \alpha_{10} &+ \sum_{k=1}^{n} \alpha_{11k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{12k}\, \Delta \ln KM_{t-k} \\ &+ \sum_{k=0}^{n} \alpha_{13k}\, \Delta \ln KP_{t-k} \\ &+ \sum_{k=0}^{n} \alpha_{14k} \Delta ln EA_{t-k} + \sum_{k=0}^{n} \alpha_{15k}\, \Delta \ln EW_{t-k} \\ &+ \sum_{k=0}^{n} \alpha_{16k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{17k}\, \Delta \ln L_{t-k} + + \theta_1 \\ &* ECT_{t-1,y} + \epsilon_{4t}\end{aligned} \quad \text{..... 4.3(a)}$$

where

$$\begin{aligned}ECT_{t-1,y} = lnY_t &- (\varphi_{12} lnKM_{t-1} + \varphi_{13} lnKP_{t-1} \\ &+ \varphi_{14} lnEA_{t-1} + \varphi_{15}\, lnEW_{t-1} + \varphi_{16}\, lnET_{t-1} + \varphi_{17}\, lnL_{t-1})\end{aligned} \quad \text{..... 4.3(b)}$$

$$\Delta ln\, EA_t = \alpha_{20} + \sum_{k=1}^{n} \alpha_{21k}\, \Delta \ln EA_{t-k} + \sum_{k=0}^{n} \alpha_{22k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{23k} \Delta ln Y_{t-k}^2 + \sum_{k=0}^{n} \alpha_{24k} \Delta ln Y_{t-k}^3 + \sum_{k=0}^{n} \alpha_{25k}\, \Delta \ln KM_{t-k} + \sum_{k=0}^{n} \alpha_{26k}\, \Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{27k} \Delta ln EW_{t-k} + \sum_{k=0}^{n} \alpha_{28k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{29k}\, \Delta \ln L_{t-k} + \theta_2 * ECT_{t-1,EA} + \in_{2,t} \quad \text{..... 4.4(a)}$$

where

$$ECT_{t-1,EA} = ln\, EA_t - (\varphi_{22}\, lnY_{t-1} + \varphi_{23}\, lnY_{t-1}^2 + \varphi_{24}\, lnY_{t-1}^3 + \varphi_{25} lnKM_{t-1} + \varphi_{26}\, lnKP_{t-1} + \varphi_{27}\, lnEW_{t-1} + \varphi_{28}\, lnET_{t-1} + \varphi_{29}\, lnL_{t-1}) \quad \text{..... 4.4(b)}$$

$$\Delta ln\, EW_t = \alpha_{30} + \sum_{k=1}^{n} \alpha_{31k}\, \Delta \ln EW_{t-k} + \sum_{k=0}^{n} \alpha_{32k}\, \Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{33k} \Delta ln Y_{t-k}^2 + \sum_{k=0}^{n} \alpha_{34k} \Delta ln Y_{t-k}^3 + \sum_{k=0}^{n} \alpha_{35k}\, \Delta \ln KM_{t-k} + \sum_{k=0}^{n} \alpha_{36k}\, \Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{37k} \Delta ln EA_{t-k} + \sum_{k=0}^{n} \alpha_{38k}\, \Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{39k}\, \Delta \ln L_{t-k} + \theta_3 * ECT_{t-1,EW} + \in_{3t} \quad \text{..... 4.5(a)}$$

where

$$ECT_{t-1,EW} = ln\, EW_t - (\varphi_{32}\, lnY_{t-1} + \varphi_{33}\, lnY_{t-1}^2 + \varphi_{34}\, lnY_{t-1}^3 + \varphi_{35} lnKM_{t-1} + \varphi_{36}\, lnKP_{t-1} + \varphi_{37}\, lnEA_{t-1} + \varphi_{38}\, lnET_{t-1} + \varphi_{39}\, lnL_{t-1}) \quad \text{..... 4.5(b)}$$

Finally, short-run dynamic ARDL land pollution model with conditional error correction term (ECT_{t-1}) is as following:

$$\Delta ln\, ET_t = \alpha_{40} + \sum_{k=1}^{n} \alpha_{41k}\,\Delta \ln ET_{t-k} + \sum_{k=0}^{n} \alpha_{42k}\,\Delta \ln Y_{t-k} + \sum_{k=0}^{n} \alpha_{43k} \Delta lnY_{t-k}^2 + \sum_{k=0}^{n} \alpha_{44k} \Delta lnY_{t-k}^3 + \sum_{k=0}^{n} \alpha_{45k}\,\Delta \ln KM_{t-k} + \sum_{k=0}^{n} \alpha_{46k}\,\Delta \ln KP_{t-k} + \sum_{k=0}^{n} \alpha_{47k} \Delta lnEA_{t-k} + \sum_{k=0}^{n} \alpha_{48k}\,\Delta \ln EW_{t-k} + \sum_{k=0}^{n} \alpha_{49k}\,\Delta \ln L_{t-k} + \theta_3 * ECT_{t-1,ET} + \epsilon_{3t} \quad \text{..... 4.6(a)}$$

where

$$ECT_{t-1,ET} = \ln EA_t - (\varphi_{42}\, lnY_{t-1} + \varphi_{43}\, lnY_{t-1}^2 + \varphi_{44}\, lnY_{t-1}^3 + \varphi_{45} lnKM_{t-1} + \varphi_{46}\, lnKP_{t-1} + \varphi_{47}\, lnEA_{t-1} + \varphi_{48}\, lnEW_{t-1} + \varphi_{49}\, lnL_{t-1}) \quad \text{..... 4.6(b)}$$

where $\theta_i * ECT_{i,t-1}$ are the conditional error-correction terms for the previous period representing the speed of adjustment that tells that how fast the variables adjust to the long-run equilibrium level. In fact, $ECT_{i,t-1}$ is a benchmark of reconciling the short-run behavior of an economic variable with its long-run behavior.

4.6 Conclusions

The data and analytical framework mentioned in present chapter is used for the empirical analysis and empirical results of Chapter 6.

CHAPTER 5

CONSTRUCTION OF INDICES

In Chapter 3, equations 3.4(a) through 3.4(f) are constructed on the basis of theories of economic growth and environmental economics as are explained by empirical evidence provided in Chapter 2, titled as literature review. In these equations 42-variables affecting capital, labor and environmental degradation are grouped into 6-indices. In present chapter, empirical construction of these indices by using techniques of principal component analysis and principal factor scoring (loading) is presented.

5.1 Construction of Indices

To make the task practicable, indices are constructed in two parts. The subsection 5.1.1 deals with the construction of indices based on the tangible physical capital, intangible monetary capital and human capital as drivers of economic growth. The subsection 5.1.2 elucidates the construction of indices related to environmental degradation.

5.1.1 Indices of Monetary, Physical and Human Capital

The variables affecting tangible physical, intangible monetary and human capital are clarified by the theories of economic growth and are utilized in theoretical construction of indices in Chapter 3. By following the procedure for construction of indices presented in Chapter 4, practical formation of these indices is presented here. After mathematical standardization of variables, the suitability of data for construction of principal component analysis (PCA) is tested by using Kaiser Meyer Olkin (Kaiser and Rice, 1974) measures of sampling adequacy (MSA). The Kaiser′s MSA is constructed from ordinary correlation coefficients for individual variable and is presented in Table 5.1. The aggregate value of MSA (0.6062) falls in the mediocre (i.e., 60-percent and above) category by Kaiser and Rice (1974) that is a feasible range for construction of indices for any data. The MSA for individual index is also provided in Table 5.1. The pair-wise correlation matrix is provided in Appendix-B.

After passing the feasibility test for construction of PCA construction, choice for the number of component (Preacher and MacCallum, 2003) is an important decision in PCA. The Table 5.1 also provides information about the number of components retained based on Kaiser-Guttman unit eigen value criterion. On the bases of this criterion only three PCs out of 23 PCs are selected. The cumulative eigen value for first three selected PCs is equal to 20.48 out of 23 (*i.e.*, sum of eigen value of 23 variables).

The monetary, physical and human capital drivers of economic growth can be divided into three PCs on the basis of Kaiser-Guttman unit eigen value criterion. Only PC's having eigen values greater than unity are retained. Columns 3 to column 5 describe the linear combination of coefficients for these retained PCs. For loading we consider the variables having more than 50 percent variation in absolute term. The first principal component (labeled as PC1) is reasonably loaded by variables namely, net inflows of foreign direct investment as a percentage of GDP (FDI_t), gross domestic saving as a percentage of GDP (GDS_t), market capitalization of listed domestic companies as a percentage of GDP (MKC_t), net domestic credit (NDC_t), net foreign assets (NFA_t), net official development Add received as a percentage of gross capital formation (ODA_t), portfolio equity, net inflows (PEQ_t), personal remittances, received as a percentage of GDP (PRR_t) and technical coorperation grants (TCG_t). So PC1 can be reasonably labeled as the index of monetary capital (KM_t).

The eigen vector (loading) of PC2 shows that it is denominated by changes in inventories (CIN_t), gross capital formation as a percentage of GDP (GCF_t), gross value added (GVA_t), medium and high-tech industry (including construction) as a percentage of manufacturing value added (MHT_t), net investment in nonfinancial assets as a percentage of GDP (NIA_t) and research and development expenditure as a percentage of GDP (RAD_t). Therefore, PC2 effectively presents the index of the non-monetary or physical capital (KP_t).

Table 5.1

Principal Components of Monetary, Physical and Human Capital

Variables	MSA	Eigenvector Loadings		
		PC1	PC2	PC3
ADR_t	0.6264	-0.2895	-0.0156	**-0.6210**
CFW_t	0.5027	0.0257	0.3354	**0.7866**
CIN_t	0.5890	0.2768	**0.6909**	0.0813
FDI_t	0.5378	**0.5172**	0.4394	0.2122
GCF_t	0.5794	-0.1533	**0.5806**	0.3821
GDS_t	0.7681	**0.6160**	-0.0122	-0.0825
GEX_t	0.5198	0.1923	0.2131	**0.5966**
GHE_t	0.5934	0.2087	-0.2508	**0.5348**
GVA_t	0.8346	0.2896	**0.6224**	0.0486
LFP_t	0.6810	0.2634	-0.0947	**0.5908**
MHT_t.	0.5769	-0.1727	**0.6482**	0.2469
MKC_t	0.5457	**0.5685**	0.1958	0.1878
NDC_t	0.6962	**0.6469**	-0.1319	0.1415
NFA_t	0.7174	**0.5517**	0.2778	-0.3268
NIA_t	0.5780	-0.0908	**0.5293**	0.2525
ODA_t	0.5600	**0.5512**	0.0205	-0.4723
PEQ_t	0.5815	**0.5060**	0.3357	-0.0512
POD_t	0.6155	-0.2784	-0.0383	**-0.6016**
PRR_t	0.6532	**0.6795**	-0.0276	-0.0618
RAD_t	0.5429	0.0920	**0.5848**	-0.0401
SFM_t	0.5447	-0.2396	0.0759	**0.5704**
TCG_t	0.5010	**0.6511**	0.0903	-0.0594
TED_t	0.5980	0.2848	0.0512	**0.6139**
Feasibility Test (Kaiser's MSA)	**0.6062**	0.6179	0.6168	0.5852
Eigenvalue (Average = 1)	**---**	11.70	5.07	3.51
Cumulative Eigenvalue (Sum =23)	**---**	11.70	16.77	20.48
Explained Proportion* (Percentage of Variance)	**---**	0.5087	0.2204	0.1526
Cumulative Proportion (Percentage of Variance)	**---**	0.5087	0.7291	0.8817

Note: Sample (1995-2022), Principal Components are computed using ordinary correlations, and only three PCs are extracted out of 23 possible components with higher explained proportions*.
Correlation matrix is provided in Appendix-B.
For symbols consider the list of abbreviations.

Finally, eigen vector (loading) of PC3 shows that it is measured by age dependency ratio as a percentage of working-age population (ADR_t), total contributing family workers as a percentage of total employment (CFW_t), government expenditure on education as a percentage of total government expenditure (GEX_t), domestic general government health expenditure per capita (GHE_t), labor force participation rate as a percentage of total population ages 15+ (LFP_t), probability of dying among youth ages 20-24 years per 1,000 (POD_t), total self-employed as a percentage of total employment (SFM_t) and educational attainment, at least completed short-cycle tertiary, population 25+ as a percentage of total population (TED_t). Thus PC3 truly presents an index of human capital , presenting labor force (L_t).

Based on correlation matrix the sum of the scaled variances for the twenty-three variables is 23, where first PC (*i.e.,* PC1) accounts for 50.87 percent of the total variance (11.70/23 = 0.5087). The second and the third PCs account for 22.04 percent and 15.26 percent of total variation, respectively. In other words, these three retained PCs account for overall 88.17 percent of the total variation. The unobserved PCs selected in the above Table 5.1 are based on the covariance structure of the observed data (monetary, physical and human capital). Therefore, after selection of the components of each index instead of using weight (loadings) from the eigen vector matrix, these unobservable PCs can be estimated through the principal factor analysis (Gorsuch, 1983; Grice, 2001; McDonald, 1981 and Green, 1969) where un-rotated Bartlett weighted least squares (WLS) regression method for the original loadings of factor coefficients (Bartlett, 1937) is used. A summary, of the factor score coefficients obtained through Bartlett weighted least squares regression estimates, is presented in Table 5.2.

Table 5.2

Drivers of Economic Growth: Monetary, Physical and Human Capital

	Exact Scoring Coefficients (on the basis of Bartlett WLS)		
	KM (Monetary Capital)	**KP (Physical Capital)**	**L (Labor)**
ADR_t	---	---	-0.1348
CFW_t	---	---	0.0934
CIN_t	---	0.1056	---
FDI_t	0.1013	---	---
GCF_t	---	0.1847	---
GDS_t	0.0842	---	---
GEX_t	---	---	0.0598
GHE_t	---	---	0.0827
GVA_t	---	0.0549	---
LFP_t	---	---	0.3242
MHT_t	---	0.3662	---
MKC_t	0.2897	---	---

NDC_t	0.1741	---	---
NFA_t	0.0551	---	---
NIA_t	---	0.1415	---
ODA_t	0.0397	---	---
PEQ_t	0.0136	---	---
POD_t	---	---	-0.0063
PRR_t	0.1138	---	---
RAD_t	---	0.0229	---
SFM_t	---	---	0.0818
TCG_t	0.0025	---	---
TED_t	---	---	0.0456
Validity of Coefficients (Multiple-R)	0.9978	0.9843	0.9759
R-squared	0.9999	0.9935	0.9912

Estimated Scores Correlation Coefficients		MK	PK	L
	MK	1.0000		
	PK	-0.0167	1.0000	
	L	0.0215	0.0479	1.0000
Estimated Factor Correlation Coefficients		MK	PK	L
	MK	1.0000		
	PK	0.0000	1.0000	
	L	0.0000	0.0000	1.0000

Goodness of Fit Summary:	
Root Mean Square Residuals (RMSR)	RMSR---0.0286 (for fitted model) RMSR---0.3267 (for independent model)
Bollen Relative Fit Index (RFI)	RFI------0.9949 (for fitted model)
Normed Fit Index (NFI)	NFI------0.9974 (for fitted model)

Note: Sample size from 1995 to 2022, and Factor scoring method is Bartlett WLS (based on un-rotated loading).

For symbols consider the list of abbreviations.

The unique-recode method proposed by Grice (2001) is used to determine simplified weights by the elements of an exact coefficient weight matrix on the basis of their magnitudes. In this method the element with the highest absolute value in a row is recoded to a non-zero value, such that each variable loads on a single factor and maintains its sign. Grice′s unique-recode method helps us to provide a complete picture of constructed indices, namely the indices of monetary capital (KM_t), physical capital (KP_t) and human capital (L_t). In Table 5.2 the index of monetary capital (KM_t), is constructed as a weighted linear combination of data for FDI_t, GDS_t, MKC_t, NDC_t, NFA_t, ODA_t, PEQ_t, PRR_t and TCG_t with weights given in the second column of exact scoring coefficients based on Bartlett WLS regression (0.1013, 0.0842, 0.2897, 0.1741, 0.0.0551, 0.0397, 0.0136, 0.1138 and 0.0025 respectively). The non-monetary or physical capital (KP_t) is a weighted average of CIN_t, GCF_t, GVA_t, MHT_t, NIA_t and RAD_t with weights given in the third column of exact scoring coefficients based on Bartlett WLS regression (0.1056, 0.1847, 0.0549, 0.3662, 0.1415, and 0.0229 respectively). The L_t is the index of human capital, presenting labor and is a weighted average of ADR_t, CFW_t, GEX_t, GHE_t, LFP_t, POD_t, SFM_t and TED_t with weights given in the fourth column of exact scoring coefficients based on Bartlett WLS regression (-0.1348, 0.0934, 0.0598, 0.0827, 0.3242, -0.0063, 0.0818 and 0.0456 respectively).

The R-squared values for these three indices of monetary capital (KM_t), physical capital (KP_t) and human capital (L_t) are 0.9999, 0.9935 and 0.9912 respectively, which show the variation in the Bartlett WLS regression explained by these selected components. The multiple-R is used to measure the validity of coefficients in each index. The multiple correlation coefficients (*i.e.*, multiple R) for the first index (principal factor) is 0.9978 whereas the multiple correlation coefficients of the second and third principal factors are 0.9843 and 0.9759 respectively, showing that the validity of coefficients for these factors are approximately equal to or in excess of 0.80, the benchmark recommended by Gorsuch (1983).

The factors score correlation coefficients (off-diagonal elements) are equal to zero based on the unique-recode method proposed by Grice (2001) where each variable load on a single factor (index) and maintain its sign, that's why across factors correlation coefficients are zero. Goodness-of-fit of these indices is measured by Bollen relative fit index (RFI) by Bollen (1986) and Bentler Bonnet normed fit index (NFI) proposed and used by Byrne (1994) and Schumacker and Lomax (2004). The RFI improves the values of these fitted indices by 99.49 percent, whereas NFI improves the fitted indices by 99.74 percent relative to independent (no factor) model.

The root mean square residuals (RMSR) as an incremental fit index is used to compare the fit of the estimated model against the independence model (Hu and Bentler, 1999). The value of the RMSR for fitted model is 0.0286 (i.e., 2.86 percent) which is less than RMSR of independent model (i.e., 0.3267 = 32.67 percent). Zero RMSR represents a perfect fit. According to Browne and Cudeck (1989) RMSR should be less than 0.08 and ideally less than 0.05 (Steiger, 1990). Thus 0.0286 value of RMSR is a token for good fit of estimated models (indices).

On the basis of explanation provided in the Table 5.2, the indices of monetary capital (KM_t), physical capital (KP_t) and human capital (L_t) arrived at through the principal component analysis and principal factor analysis, take the following form.

$$KM_t = 0.1013\,FDI_t + 0.0842\,GDS_t + 0.2897\,MKC_t + 0.1741\,NDC_t + 0.0551\,NFA_t + 0.0397\,ODA_t + 0.0136\,PEQ_t + 0.1138\,PRR_t + 0.0025\,TCG_t \quad \ldots 5.1$$

$$KP_t = 0.1056\,CIN_t + 0.1847\,GCF_t + 0.0549\,GVA_t + 0.3662\,MHT_t + 0.1415\,NIA_t + 0.0229\,RAD_t \quad \ldots 5.2$$

and

$$L_t = -0.1348\,ADR_t + 0.0934\,CFW_t + 0.0598\,GEX_t + 0.0827\,GHE_t + 0.3242\,LFP_t - 0.0063\,POD_t + 0.0818\,SFM_t + 0.0456\,TED_t \quad \ldots 5.3$$

In the index of intangible monetary capital (KM_t) all the components (i.e., FDI_t, GDS_t, MKC_t, NDC_t, NFA_t, ODA_t, PEQ_t, PRR_t and RCG_t) provide monetary incentives to rational producer and hence they all have positive weights (loadings) for this index. Where the FDI_t is net inflows of foreign direct investment as a percentage of GDP, GDS_t is gross domestic savings as a percentage of GDP, MKC_t is market capitalization of listed domestic companies as a percentage of GDP, NDC_t is net domestic credit, NFA_t is net foreign assets, ODA_t is net official development add received as a percentage of gross capital formation, PEQ_t is portfolio equity net inflows, PRR_t is personal remittances received as a percentage of GDP, and RCG_t is technical coorporation grants that provide monetary incentives to rational expected utility maximizers hence they all have positive weights (loadings). The loading of net inflows of foreign direct investment as a percentage of GDP (FDI_t) to monetary capital in the equation (5.1) is 0.1013. It shows that net inflows of foreign direct investment as a percentage of GDP in Pakistan are able to increase the value of Pakistan's monetary assets by 10.13 percent. A strong monetary sector generates financial resources by raising savings and distributes these resources to running investment and to setup new business that leads to infrastructure development and hence an increase in monetary assets of Pakistan.

The influx of FDI_t, NFA_t, ODA_t, PEQ_t, PRR_t and RCG_t helps to develop financial market, such as banking system and stock exchange (Aryani and

Pratamasari, 2018) and hence affect incursion of money to the host country. The existence of proper financial market in a country marks its attractive place for investment that expands MKC_t and NDC_t for that striking monetary hub and facilitates higher economic growth in future. A strong monetary sector generates financial resources by raising savings (GDS_t) and distributes these resources to running investment and to setup new business that leads to infrastructure development and hence a further increase in monetary and physical assets of Pakistan. The gross domestic savings as a percentage of GDP (GDS_t) has loading score of 0.0842 (i.e., 8.42 percent) for monetary capital.

The tangible non-monetary or physical capital (KP_t) in equation (5.2) has positive weights (loadings) for changes in inventories (CIN_t), gross capital formation as a percentage of GDP (GCF_t), gross value added (GVA_t), medium and high-tech industry (including construction) as a percentage of manufacturing value added (MHT_t), net investment in nonfinancial assets as a percentage of GDP (NIA_t) and the research and development expenditure as a percentage of GDP (RAD_t). All above mentioned components of non-monetary capital specifically, investment, capital formation and infrastructure development positively affects physical capital. The physical capital consists of man-made goods that assist in the production process, so Majaski (2021) consider cash, equipment, real estate, and inventory as components of physical capital. Massell (1960) examined the annual increase in output per man hour of labor in the US economy between 1919 and 1955, and he considered technological change $(MHT)_t$ and (RAD_t) as nebulous constellation of forces for an increase in average productivity of labor and hence for physical capital formation (KP_t).

The index of human capital (L_t) is positively loaded by total contributing family workers as a percentage of total employment (CFW_t), domestic general government health expenditure per capita (GHE_t), educational attainment at least completed short-cycle tertiary education for population ages 25+ as a percentage of total population (TED_t), government expenditure on education as a percentage of total government expenditure (GEX_t), labor force participation rate as a percentage of total population ages 15+ (LFP_t) and total self-employed as a percentage of total employment (SFM_t). Whereas the index of L_t is negatively loaded by age dependacy ratio as a percentage of working-age population (ADR_t) and probability of dying among youth ages 20 to 24 years per one-thousand (POD_t). Both these variables (ADR_t and POD_t) have negative effect on labor productivity and hence on physical capital formation. Sultana et al., (2019) indicated that the factors such as formal education and knowledge, skills and competencies (like TED_t, GEX_t), health (GHE_t), job experience, organizational training, creativity and innovation capability, (CFW_t, LFP_t, and SFM_t) have a positive and statistically significant relationship with the human capital formation. On the other hand a higher dependency ratio diminishes productive capacity and hence increases non-productive population. Stoler and Meltzer (2013) provided theoretical reasons to expect that high risk of morbidity and mortality in adulthood decreases investment in human capial and hence human capial formation.

5.1.2 The Indices for Environmental Degradation

In this subsection the indices of the environmental degradation specifically, air pollution (EA_t), water pollution (EW_t) and land pollution (ET_t) are constructed. After mathematical standardization of variables, the suitability of data for principal component analysis (PCA) is tested by using Kaiser-Guttman unit eigen value criterion. The Kaiser′s MSA for individual variable and for aggregate data is presented in the Table 5.3. The aggregate value of MSA (0.8561) falls in the meritorious (i.e., 80-percent and above) category by Kaiser and Rice (1974) that is a feasible range for construction of indices for that data. The pair-wise correlation matrix is provided in Appendix-C.

After passing the feasibility test for construction of PCA, Table 5.3 also provides information about the number of components retained based on Kaiser-Guttman unit eigen value criterion. On the bases of this criterion only three PCs out of 19 PCs are selected. The cumulative eigen value for first three selected PCs is equal to 17.31 out of 19 (*i.e.*, sum of eigen value of 19 variables).

The first principal component (labeled as PC1) is reasonably loaded by variables namely, access to clean fuels and technologies for cooking as a percentage of population (ACF_t), CO_2 emissions, metric tons per capita (COE_t), fossil fuel energy consumption as a percentage of total consumption (FFC_t), other greenhouse gas emissions, HFC, PFC and SF6 thousand metric tons of CO_2 equivalent (OGG_t), methane emissions kiloton of CO_2 equivalent (MET_t), nitrous oxide emissions in energy sector as a percentage of total emissions (NOE_t) and electricity production from oil, gas and coal sources as a percentage of total electricity production (OGC_t). So PC1 can be reasonably labeled as an index of environmental degradation through air pollution (EA_t).

The eigen vector (loading) of PC2 shows that it is denominated by people using at least basic sanitation services as a percentage of total population (BSS_t), container port traffic (CPT_t), renewable internal freshwater resources per capita (FWR_t) and people using safely managed drinking water services as a percentage of total population (SMW_t). Therefore, PC2 effectively presents the index of the environmental degradation through water pollution (EW_t).

Table 5.3

Principal Components for Environmental Degradation

Variables	MSA	Eigenvector Loadings		
		PC1	PC2	PC3
ACF_t	0.8790	**-0.6483**	0.0522	-0.0252
AME_t	0.8154	-0.2376	-0.1605	**0.5490**
ANE_t	0.8834	0.2390	0.0156	**0.5459**
BSS_t	0.8028	0.2478	**-0.6154**	0.0281
CLA_t	0.7473	0.1987	0.4175	**-0.5954**
COE_t	0.9251	**0.6344**	0.0963	0.1098
CPT_t	0.8237	0.2453	**0.6158**	0.0148
EAS_t	0.7564	-0.1686	0.3489	**-0.5405**
FCN_t	0.9415	0.2375	0.1262	**0.5464**
FWR_t	0.9040	-0.2462	**-0.6075**	0.0392
OGG_t	0.8483	**0.6271**	-0.2668	-0.0852
MET_t	0.9448	**0.6441**	0.1077	0.0549
NOE_t	0.8785	**0.6314**	0.0743	-0.1358
ODE_t	0.8206	-0.2477	-0.0202	**0.5567**
OGC_t	0.5105	**0.5106**	0.6135	-0.5828
OMX_t	0.9112	0.2332	-0.0868	**0.5322**
PDN_t	0.9632	0.2475	0.0292	**0.5571**
SMW_t	0.7912	-0.2054	**-0.5588**	-0.0831

URP_t	0.8820	0.2476	0.0399	**0.5578**
Feasibility Test (Kaiser's MSA)	**0.8561**	**0.8310**	**0.8304**	**0.8579**
Eigenvalue (Average = 1)	---	11.1984	3.4114	2.7025
Cumulative Eigenvalue (Sum =19)	---	11.1984	14.6098	17.3123
Explained Proportion* (Percentage of Variance)	---	0.5894	0.1795	0.1422
Cumulative Proportion (Percentage of Variance)	---	0.5894	0.7689	0.9111

Note: Sample (1995-2022), Principal Components are computed using ordinary correlations, and only three PCs are extracted out of 19 possible components with higher explained proportions*.
Correlation matrix is provided in Appendix-C.
For symbols consider the list of abbreviations.

Finally, eigen vector (loading) of PC3 shows that it is measured by agricultural methane emissions as a percentage of total emissions (AME_t), permanent cropland as a percentage of land area (CLA_t), employment in agriculture as a percentage of total employment (EAS_t), fertilizer consumption, kilograms per hectare of arable land (FCN_t), people practicing open defecation as a percentage of population (ODE_t), ores and metals exports as a percentage of merchandise exports (OMX_t), population density i.e., people per sq. km of land area (PDN_t), and urban population as a percentage of total population (URP_t). Thus PC3 truly presents an index of environmental degradation through land pollution (ET_t).

Based on correlation matrix the sum of the scaled variances for the nineteen variables is 19, where first PC (i.e., PC1) accounts for 58.94 percent of the total variance (11.1984/19 = 0.5894). The second and the third PCs account for 17.95 percent and 14.22 percent of total variation, respectively. In other words these three retained PCs account for overall 91.11 percent of the total variation. The unobserved PCs selected in the above Table 5.3 are based on the covariance structure of the observed data (air, water and land pollution). Therefore, after selection of the components of each index instead of using weight (loadings) from the eigenvector matrix, these unobservable PCs can be estimated through the principal factor analysis (Gorsuch, 1983; Grice, 2001; McDonald, 1981 and Green, 1969) where un-rotated Bartlett weighted least squares (WLS) regression method for the original loadings of factor coefficients (Bartlett, 1937) is used. A summary, of the factor score coefficients obtained through Bartlett weighted least squares regression estimates, is presented in Table 5.4 below.

The unique-recode method proposed by Grice (2001) is used to determine simplified weights by the elements of an exact coefficient weight matrix on the basis of their magnitudes. In this method the element with the highest absolute value in a row is recoded to a non-zero value, such that each variable load on a single factor and maintains its sign. Grice′s unique-recode method helps to provide a complete picture of constructed indices, namely the indices of environmental degradation through air pollution (EA_t), environmental degradation through water pollution (EW_t) and environmental degradation through land (ET_t).

Table 5.4

Determinants of Air, Water and Land Pollution

	Exact Scoring Coefficients (on the basis of Bartlett WLS)		
	EA (Air Pollution)	**EW (Water Pollution)**	**ET (Land Pollution)**
ACF_t	-0.1638	---	---
AME_t	---	---	0.0349
ANE_t	---	---	0.0425
BSS_t	---	-0.2854	---
CLA_t	---	---	-0.1039
COE_t	0.2874	---	---
CPT_t	---	0.1618	---
EAS_t	---	---	-0.1324
FCN_t	---	---	0.1534
FWR_t	---	-0.2575	---
OGG_t	0.1341	---	---
MET_t	0.1177	---	---
NOE_t	0.1525	---	---
ODE_t	---	---	0.1325
OGC_t	0.0721	---	---
OMX_t	---	---	0.0536
PDN_t	---	---	0.1811
SMW_t	---	-0.1088	---
$\boldsymbol{URP_t}$	**---**	**---**	**0.0728**
Validity of Coefficients (Multiple-R)	0.9987	0.9877	0.9696
R-squared	0.9974	0.9854	0.9682

Estimated Scores Correlation Coefficients		EA	EW	ET
	EA	1.0000		
	EW	-0.0399	1.0000	

	ET	0.0417	-0.0667	1.0000
Estimated Factor Correlation Coefficients		EA	EW	ET
	EA	1.0000		
	EW	0.0000	1.0000	
	ET	0.0000	0.0000	1.0000

Goodness of Fit Summary:	
Root Mean Square Residuals (RMSR)	RMSR---**0.0306** (for fitted model)
	RMSR---**0.4811** (for independent model)
Bollen Relative Fit Index (RFI)	RFI------**0.9983** (for fitted model)
Normed Fit Index (NFI)	NFI------**0.9986** (for fitted model)

Note: Sample size from 1995 to 2022, and Factor scoring method is Bartlett WLS (based on un-rotated loading).
For symbols consider list of abbreviations.

In Table 5.4 the index of environmental degradation through air pollution (EA_t) is constructed as a weighted linear combination of data for ACF_t, COE_t, OGG_t, MET_t, NOE_t and OGC_t with weights given in the second column of exact scoring coefficients based on Bartlett WLS regression (-0.1638, 0.2874, 0.1341, 0.1177, 0.1525 and 0.0721 respectively).

The environmental degradation through water pollution (EW_t) is a weighted average of BSS_t, CPT_t, FWR_t, and SMW_t with weights given in the third column of exact scoring coefficients based on Bartlett WLS regression (-0.2854, 0.1618, -0.2575 and -0.1088 respectively). The environmental degradation through land pollution (ET_t) is a weighted average of AME_t, ANE_t, CLA_t, EAS_t, FCN_t, ODE_t, OMX_t, PDN_t and URP_t with weights given in the fourth column of exact scoring coefficients based on Bartlett WLS regression (0.0349, 0.0425, -0.1035, -0.1324, 0.1534, 0.1325, 0.0536, 0.1811 and 0.0728 respectively).

The R-squared values for these three indices of EA_t, EW_t and ET_t are 0.9974, 0.9854 and 0.9682 respectively, which show the variation in the Bartlett WLS regressions explained by these selected components. The multiple-R is used to measure the validity of coefficients in each index. The multiple correlation coefficients (i.e., multiple R) for the first index (principal factor) is 0.9987 whereas the multiple correlation coefficients of the second and third principal factors are 0.9877 and 0.9696 respectively, showing that the validity of coefficients for these factors are approximately equal to or in excess of 0.80, the benchmark recommended by Gorsuch (1983).

The factors score correlation coefficients (off-diagonal elements) are equal to zero based on the unique-recode method proposed by Grice (2001) where each variable loads on a single factor (index) and maintain its sign, that's why across factors correlation coefficients are zero. Goodness-of-fit of these indices is measured by Bollen relative fit index (RFI) by Bollen (1986) and Bentler Bonnet normed fit index (NFI) proposed and used by Byrne (1994) and Schumacker and Lomax (2004). The RFI improves the values of these fitted indices by 99.83 percent, whereas NFI improves the fitted indices by 99.86 percent relative to independent (no factor) model.

The root means square residuals (RMSR) as an incremental fit index is used to compare the fit of the estimated model against the independence model (Hu and Bentler, 1999). The value of the RMSR for fitted model is 0.0306 (i.e., 3.06 percent) which is less than RMSR of independent model (i.e., 0.4811 = 48.11 percent). Zero RMSR represents a perfect fit. According to Browne and Cudeck (1989) RMSR should be less than 0.08 and ideally less than 0.05 (Steiger, 1990). Thus 0.0306 value of RMSR is a token for good fit of estimated models (indices).

On the basis of explanation provided in the Table 5.4, the indices of EA_t, EW_t and ET_t arrived at through the principal component analysis and principal factor analysis, take the following form.

$$\begin{aligned} EA_t = & -0.1638\ ACF_t + 0.2874\ C0E_t + 0.1341\ OGG_t + 0.1177\ MET_t \\ & +0.1525\ NOE_t + 0.0721\ OGC_t \end{aligned} \qquad \ldots 5.4$$

$$EW_t = -0.2854\ BSS_t + 0.1618\ CPT_t - 0.2575\ FWR_t - 0.1088\ SMW_t \qquad \ldots 5.5$$

and

$$\begin{aligned} ET_t = & \ 0.0349\ AME_t + 0.0425\ ANE_t - 0.1039\ CLA_t - 0.1324\ EAS_t + 0.1534\ FCN_t \\ & + 0.1325\ ODE_t + 0.0536\ OMX_t + 0.1811\ PDN_t + 0.0728\ URP_t \end{aligned} \qquad \ldots 5.6$$

In the index of environmental degradation through air pollution (EA_t) all the components (i.e., COE_t, OGG_t, MET_t, NOE_t, and OGC_t) have damaging effects on air hence they all have positive weights (loadings) for air pollution. The access to clean fuels and technologies for cooking as a percentage of total population (ACF_t) has negative loading for air pollution. The loading of ACF_t to EA_t in the equation (5.4) is -0.1638 (i.e., 16.38 percent). It shows that the access to clean fuels and technologies for cooking as a percentage of total population (ACF_t) help to decrease deterioration of air quality and less reliance on traditional cooking methods of wood and coal burning hence it has negative loading for air pollution. Khan et al., (2020) detected positive effect of energy consumption and economic growth on the CO_2 emission in Pakistan both in short-run and long-run. According to *Dickinson* et al., (2015) cooking over open fires ignites environmental issues of air pollution by trash burning, different types of commercial cooking, and vehicle emissions. Jalil and Mahmud (2009) examined that the carbon emissions are determined by income and energy consumption.

Whereas in the index of EW_t, all the components (i.e., BSS_t, FWR_t and SMW_t) have negative role in infuriating water pollution. An increase in the people using at least basic sanitation services as a percentage of population (BSS_t), renewable internal freshwater resources per capita (FWR_t) and people using safely managed drinking water services as a percentage of total population (SMW_t) are environment friendly services that help to reduce water pollution and thus have negative loading scores (-0.2854, -0.2575 and -0.1088 respectively). Whereas container port traffic (CPT_t) with positive weights (loading, 0.1618) increases the water pollution at steam, rivers and sea shores. Templeton et al., (2015) indicated that in areas with a near-surface aquifer, the potential for nitrate pollution arising from pit latrines is worrisome. Khatri and Tyagi (2014) stated that in rural and urban areas of developing countries, ground and surface water is affected by natural and biological processes. They further stated that anthropogenic factors affecting water quality include impacts of agriculture, use of fertilizers, manures and pesticides, animal husbandry activities, wasteful irrigation practices, woods cutting, aquaculture, pollution due to industrial wastes and domestic sewage, mining and recreational activities.

In the index of ET_t, all the components (i.e., CLA_t, EAS_t, FCN_t, ODE_t, OMX_t, PDN_t and URP_t have positive weights indicating that an increase in them aggravates the land pollution. Only an increase in permanent cropland as a percentage of land area (CLA_t) helps to decrease the land pollution. According to Zhang and Wang (2020) human factors responsible for land pollution are abandoned mining areas, intensive application of fertilizer and pesticide, and sewage irrigation. Bai et al., (2020) examine the impact of agglomeration factors namely improvement in educational level, non-agricultural employment ratio, disaster ratio, and farmer's income on fertilizer use efficiency and hence on environmental contamination. Chandhni et al., (2019) gauged the effect of chemical fertilizers on environment and ecosystem. They stated that the fertilizer as an input in crop production depletes the environment and ecosystem by eating up the natural resources and by threatening the life on earth.

5.2 Conclusions

The indices for drivers of economic growth (monetary, physical and human capital) and for sources of environmental degradation (air, water and land pollution) constructed in present chapter are utilized for empirical analysis of Chapter 6.

CHAPTER 6

EMPIRICAL RESULTS

In present chapter the empirical findings for the sources of environmental degradation beside their impact on economic growth of Pakistan are presented.

6.1 The Results of Augmented Dicky Fuller Unit Root Test

The unit-root test namely, augmented Dicky-Fuller (ADF) test is performed to examine the stationarity of all constructed indices and relevant variables. This step is necessary to test the order of integration of the variables included in environmental degradation and economic growth models. The summary of the results of ADF unit-root test is presented in Table 6.1.

The null hypothesis is that series (or indices) has individual unit-root i.e., series is non-stationary. The ADF unit-root test is based on the probability of t-statistic achieved through the least square method. Only results based on the lag length selected by automatic selection procedure of Schwarz Information Criterion are considered in Table 6.1. The bold values in the Table 6.1 have t-calculated greater than t-critical and hence reject the null hypothesis of presence of unit-root in the individual series. The results obtained from ADF unit-root test acquiesce that all series have unit-root at level of lag length one, i.e., they all are non-stationary at level of lag length one (presented in 1st part of Table 6.1). Remarkably, all the series are stationary (specifically, $lnEA_t$, $lnET_t$, $lnEW_t$, $lnKM_t$, $lnKP_t$, lnL_t, lnY_t) at first difference of lag length one with-intercept and without trend but these series show mixed results for with and without intercept and trend. For example, $lnET_t$ is non-stationary at first difference “without-intercept and without-trend” at lag length one but is stationary “with-intercept” and “with-intercept and with-trend” for first difference at lag length one.

Table 6.1

Results of Augmented Dicky Fuller (ADF) Test for Stationarity

H_0: Non-Stationary Series (*i.e.*, Series for indices has individual Unit Root)

Series	Coefficients	Lag Length One			I(d) @ 5 % level of significance
		No intercept &no trend	**Intercept**	**Intercept & trend**	
Level	$lnEA_t$	-0.0117	-0.0217	-0.5630	
	t-stats	(-1.8941)	(-0.4161)	(-3.1532)	Non-stationary at level
	Prob [t-stats]	[0.0703]	[0.6811]	[0.0046]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9550	-2.9862	-3.6032	
	$lnET_t$	-0.0038	-0.0523	-0.4296	
	t-stats	(-1.0355)	(-1.6854)	(-2.4515)	Non-stationary at level
	Prob [t-stats]	[0.0082]	[0.1102]	[0.0226]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9550	-2.9862	-3.6032	
	$lnEW_t$	-0.0059	-0.0724	-0.2537	
	t-stats	(-0.4309)	(-2.0967)	(-1.8379)	Non-stationary at level
	Prob [t-stats]	[0.0022]	[0.0472]	[0.0796]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9550	-2.9862	-3.6032	
	$lnKM_t$	-0.0024	-0.0017	-0.1953	
	t-stats	(-1.5764)	(-0.2323)	(-2.1415)	Non-stationary at level
	Prob [t-stats]	[0.0172]	[0.8185]	[0.0447]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9550	-2.9862	-3.6032	
	$lnKP_t$	-0.0033	-0.0411	-1.0815	
	t-stats	(-1.4098)	(-0.7172)	(-2.1296)	Non-stationary at level
	Prob [t-stats]	[0.0228]	[0.4819]	[0.0296]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9550	-2.9862	-3.6032	
	lnL_t	-0.0116	-0.0658	-0.5751	
	t-stats	(-1.6345)	(-1.5493)	(-2.7010)	Non-stationary at level
	Prob [t-stats]	[0.0145]	[0.1350]	[0.0130]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9550	-2.9862	-3.6032	
	lnY_t	0.0010	-0.0057	-1.2709	
	t-stats	(1.6680)	(-0.2137)	(-2.5203)	Non-stationary at level
	Prob [t-stats]	[0.1095]	[0.8328]	[0.0007]	(t-stats < t-critical) in absolute terms
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6584	

Series	Coefficients	Lag Length One			I(d) @ 5 % level of significance (with lag length one)
		No intercept &no trend	Intercept	Intercept & trend	
First Difference	$\Delta lnEA_t$	-0.8803**	-1.0499**	-1.0460**	I(1) at all the three options
	t-stats	(-4.3182)	(-5.0908)	(-4.9327)	
	Prob[t-stats]	[0.0003]	[0.0000]	[0.0001]	
	* Critical-t @ 5%	-1.9556	-2.9918	-3.6121	
	$\Delta lnET_t$	-0.1827	-2.0918**	-2.2957**	I(1) with intercept I(1) with intercept & with trend
	t-stats	(-0.8634)	(-4.7207)	(-5.1346)	
	Prob [t-stats]	[0.3999]	[0.0002]	[0.0001]	
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6121	
	$\Delta lnEW_t$	-0.5248**	-0.7686**	-0.8343**	I(1) at all the three options
	t-stats	(-3.0227)	(-3.7413)	(-3.8951)	
	Prob [t-stats]	[0.0061]	[0.0011]	[0.0008]	
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6121	
	$\Delta lnKM_t$	-0.0384	-0.5102**	-0.5109	I(1) with intercept
	t-stats	(-0.6583)	(-3.7436)	(-2.6817)	
	Prob [t-stats]	[0.5168]	[0.0119]	[0.0140]	
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6121	
	$\Delta lnKP_t$	-0.8236**	-1.5522**	-1.5529**	I(1) at all the three options
	t-stats	(-3.1787)	(-8.5600)	(-8.3824)	
	Prob [t-stats]	[0.0049]	[0.0000]	[0.0000]	
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6121	
	ΔlnL_t	-0.9210**	-1.2083**	-1.2585**	I(1) at all the three options
	t-stats	(-4.5571)	(-5.8621)	-5.9979	
	Prob [t-stats]	[0.0001]	[0.0000]	[0.0000]	
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6121	
	ΔlnY_t	-0.2826**	-0.4933**	-0.5131	I(1) with no intercept & no trend I(1) with intercept
	t-stats	(-1.9955)	(-3.9587)	(-2.6417)	
	Prob [t-stats]	[0.0580]	[0.0143]	[0.0153]	
	*Critical-t @ 5%	-1.9556	-2.9918	-3.6121	

Note: Method used is least square, in parenthesis (.) are t-statistics, unit root test is applied by using Prob [t-Statistics], lag length one is selected on the basis of automatic selection procedure of Schwarz Information Criterion.

***** values are the probabilities computed assuming asymptotic normality at 5-percent level of significance.

** shows that coefficients are significant at 5% level of significance.

Similarly, lnY_t is non-stationary at first difference "with-intercept and with-trend" at lag length one but is stationary "without-intercept and without-trend" and "with-intercept only" for first difference at lag length one (presented in 2nd part of Table 6.1. In short, the results of Table 6.1 show that though some of the variables are non-stationary at level yet all the variables become stationary at first difference, which is an indication of their possible co-integration or long-run association.

6.2 The Results of ARDL Bound Test for Co-integration

Pesaran et al. (2001) directed that ARDL Bound test can be applied to series that are integrated of order one I(1), integrated of order zero I(0), or is the combination of both.

Table 6.2

Results of Autoregressive Distributional lag Bound Test for Co-integration
Hull hypothesis: No levels relationship

	Air Pollution ($lnEA_t$)	**Water Pollution ($lnEW_t$)**	**Land Pollution ($lnET_t$)**	**Growth rate per Capita (lnY_t)**
Maximum lags Imposed	(2, 2)	(2, 2)	(2, 2)	(2,2)
Lags selected by Schwarz information criterion	(2,1,2,0,2,0,2,0,0)	(1,2,2,2,2,0,2,1,1)	(2,1,1,1,0,0,1,2,0)	(2,2,0,2,1,0,1)
F-stats Bounds Test	9.9467	9.1239	8.8479	8.2092
Error Correction Term	-0.9602***	-0.7083***	-0.8228***	-0.3001***
ECT_{t-1} Prob (t-Stats)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Outcome/Result	Co-integration exists	Co-integration exists	Co-integration exists	Co-integration exists
Lower Bound I(0) Critical Values for n = 30				
10%	2.457			
5%	2.970			
1%	4.270			
Upper Bound I(1) Critical Values for n = 30				
10%	3.797			
5%	4.499			
1%	6.211			

Note: Co-integration test is applied by using F-statistics Bounds test.
*, **, and *** represents 10%, 5%, and 1% level of significance, respectively.

Results of Table 6.1 for ADF test for stationarity suggests that almost all series (indices) are integrated of order one I(1), therefore it is valid to use ARDL Bound test to check the feasibility of co-integration between the variables. As the F-statistics is sensitive to the number of lags imposed in the model, Schwarz Information criterion (SIC) of section 6.1 (above) is also appropriate for the selection of smallest possible lags for the ARDL model. The Table 6.2 provides a summary of the results of ARDL Bound test for feasibility of co-integration analysis.

The computed F-statistics for all types of pollution and for growth rate per capita is greater than the upper-bound critical values at 10%, 5%, and 1% levels of significance, which support the presence of co-integration in these indices (variables). The presence of co-integration is also supported by the statistically significant and negative values of ECT_{t-1} in all these indices (variables). Basically, ECT_{t-1} measures the speed of adjustment that how quickly the short-run shocks can be corrected toward the long-run equilibrium level. The negative and significant values of ECT_{t-1} indicate the short-run shocks are quickly adjusted to the long-run equilibrium for all these dependent variables.

6.3 The Results of Autoregressive Distributional Lag Model

As all the variables are stationary at first difference (result of Table 6.1), a long-run association between the variables without conditional error correction term are applied in Table 6.3. Where the ARDL models are generally interpreted as least square regressions using lag of dependent and independent variables as regressors. For precision and to be specific only relevant heteroscedasticity and autocorrelation consistent (HAC) coefficients of this model are presented in Table 6.3.

The top portion of the Tables 6.3 summarizes the settings used in estimation and show the deterministic trend assumptions and the lags and leads specification used in present analysis. In the second portion of the table the estimated coefficients of long-run dynamic regression model without conditional error correction term, their t-statistics and probabilities are presented. In the third section of Table 6.3 goodness of fit indicators for ARDL model are provided. In the second section of the Table 6.3, the majority of the parameters have predicted signs compatible with the theories of environment and environmental Kuznet Curve (EKC). Table 6.3 not contains the coefficients of lagged co-integrating dynamic regressors, though these lagged dynamic parameters are used to construct the goodness of fit statistics and to compute the residuals. The high values of R^2 and adjusted R^2 show that the fitted models are good. The probabilities of F-statistics are used to check the null hypothesis for joint significance of the co-integrating regression coefficients. Though Durban Watson d-statistics is mentioned in this table yet its value is not valid in ARDL model. Therefore Breusch-Godfrey serial correlation Langrange multiplier test is used in present study.

It is worthwhile to interpret the meaning of various parameter estimates of ARDL model in detail. As equations 4.2(a) through 4.6(b) are in double-log-form, so the coefficients of the explanatory variables (indices) are representative of the elasticities of dependent variable with respect to the relevant independent variables.

Though indices are unit free variables, yet each index is a combination of more than single variable therefore interpretation of the sign of each coefficient is a little bit technical. In the Table 6.3 the estimated equations of environmental degradation and economic growth of Pakistan for dynamic regression ARDL model without conditional error correction term are presented. In all the four equations the intercept coefficients are positive (28.8794, 2.7704, 0.5496 and 12.0473) and have significant t-values, therefore they are retained in all the four equations as unrestricted fixed regressors. The trend variables because of their insignificant t-values are not considered in these dynamic regression ARDL models. The short-run association between the variables with conditional error correction terms are presented in the Table 6.4.

The positive coefficients of lnY_t specifically, 0.3166, 0.2675 and 0.2243 are the long-run elasticities of air pollution, water pollution and land pollution with respect to lnY_t Similarly, the positive coefficients of ΔlnY_t specifically, 0.3372, 0.2405 and 0.2151 are the short-run elasticities of air pollution, water pollution and land pollution with respect to ΔlnY_t. The significant positive values of these coefficients indicate that all the three type of pollutions increases in early stage of economic growth and development.

The negative coefficients of lnY_t^2 are 0.0616, 0.0738 and 0.0445 that are long-run elasticities of air pollution, water pollution and land pollution with respect to lnY_t^2. The insignificant negative values of these elasticities indicate that all the three type of pollutions are not affected by second stage of economic growth and development i.e., not yet achieved by Pakistan.

Table 6.3

Estimation Results of Long-run ARDL Model Without Error Correction Term

Dependent Variables	**Air Pollution ($lnEA_t$)**	**Water Pollution ($lnEW_t$)**	**Land Pollution ($lnET_t$)**	**Growth rate per Capita (lnY_t)**
Dynamic Regressors	lnY_t, lnY_t^2, lnY_t^3, $lnKM_t$, $lnKP_t$, lnL_t, $lnEW_t$, $lnET_t$	lnY_t, lnY_t^2, lnY_t^3, $lnKM_t$, $lnKP_t$, lnL_t, $lnEA_t$, $lnET_t$	lnY_t, lnY_t^2, lnY_t^3, $lnKM_t$, $lnKP_t$, lnL_t, $lnEA_t$, $lnEW_t$	$lnKM_t$, $lnKP_t$, lnL_t $lnEA_t$, $lnEW_t$, $lnET_t$
Fixed Regressor	Unrestricted Constant without trend			
Selected ARDL Model by SIC	(2,1,2,0,2,0,2,0,0)	(1,2,2,2,2,0,2,1,1)	(2,1,1,1,0,0,1,2,0)	(2,2,0,2,1,0,1)
C	28.8794***	2.7704***	0.5496***	12.0473***
(t-stats)	(4.9148)	(2.1054)	(2.3481)	(2.6994)
prob [t-stats]	[0.0006]	[0.0039]	[0.0043]	[0.0035]
lnY_t	0.3166***	0.2675***	0.2243***	-----
(t-stats)	(2.8658)	(3.6629)	(2.3481)	
prob [t-stats]	[0.0068]	[0.0052]	[0.0043]	
lnY_t^2	-0.0616	-0.0738	-0.0445	-----
(t-stats)	(-1.0687)	(-1.0466)	(-1.4795)	
prob [t-stats]	[0.3103]	[0.3907]	[0.2672]	
lnY_t^3	0.0078	0.0067	0.0099	-----
(t-stats)	(1.3155)	(1.5014)	(1.4917)	
prob [t-stats]	[0.3696]	[0.3149]	[0.2637]	
$lnKM_t$	-0.3288***	-0.2623**	-0.2093***	0.1582***
(t-stats)	(-5.3047)	(-3.2722)	(-6.2723)	(2.1216)
prob [t-stats]	[0.0003]	[0.0113]	[0.0001]	[0.0024]
$lnKP_t$	0.4169***	0.1335***	0.0766**	0.3323**
(t-stats)	(2.4678)	(3.4745)	(2.2122)	(2.4834)
prob [t-stats]	[0.0036]	[0.0038]	[0.0240]	[0.0221]
lnL_t	-0.3181***	-0.3923**	-0.1613**	0.4535***
(t-stats)	(-3.6711)	(-2.5336)	(-2.4322)	(2.4539)
prob [t-stats]	[0.0043]	[0.0351]	[0.0333]	[0.0024
$lnEA_t$	-----	0.0357**	0.0568***	-0.0688**
(t-stats)		(2.8911)	(6.4758)	(-2.1743)
prob [t-stats]		[0.0202]	[0.0000]	[0.0204]
$lnEW_t$	0.1283**	-----	0.04426**	-0.1519**
(t-stats)	(3.9041)		(2.0754)	(-1.9642)
prob [t-stats]	[0.0372]		[0.0132]	[0.0256]
$lnET_t$	0.0972***	0.0582***	-----	-0.2191**
(t-stats)	(3.5434)	(5.2513)		(-2.4951)
prob [t-stats]	[0.0002]	[0.0008]		[0.0391]
Diagnostic Tests				
R^2	0.9836	0.9878	0.9859	0.9889
Adjusted R^2	0.9753	0.9738	0.9715	0.9772
F-Statistics	119.6004	247.5396	225.9821	593.1782
Prob[F-Statistics]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Schwarz Criterion	-1.9566	-4.0235	-6.7051	-7.7441
Durban Watson d-stats[(b)]	1.9922	2.0098	2.0456	2.0447
Breusch-Godfrey Serial correlation LM Test				
Null Hypothesis of serial correlation in the residual up to two lags				
F-Stats	0.6411	4.6851	1.2494	2.7961
Prob [F-Stats]	[0.5517]	[0.1595]	[0.3320]	[0.1281]
$n.R^2$	3.3154	4.6312	5.2156	7.6584
Prob(2lag)Chi-square	[0.1906]	[0.1759]	[0.1737]	[0.4865]

Note: (a). Sample size 1995 to 2022, Schwarz Information Criterion (SIC) is used as a model selection method, maximum dynamic regressors 2 lags (automatic selection).

(b). shows that Durbin Watson d-stats is not depicting autocorrelation in ARDL, so residual diagnostic test of Breusch-Godfrey Serial correlation LM Test is used.

(c). *, **, and *** represent 10%, 5% and 1% level of significance, respectively.

(d). For Symbols consider list of abbreviations.

The positive coefficients of lnY_t^3 are 0.0078, 0.0067 and 0.0099 that are long-run elasticities of air pollution, water pollution and land pollution w.r.t respect to lnY_t^3 also provide insignificant positive values of these elasticities indicating that all the three type of pollutions deteriorating for underdeveloped economy of Pakistan that is till now trapped in the first stage of economic development. In short, the polynomial inverted U-shaped or N-shaped environmental Kuznets curve not holds for Pakistan. Instead, a linear environmental Kuznets curve truly depicts the early stages of economic growth and development in Pakistan.

The $lnKM_t$ is an index of intangible monetary capital that is a weighted average of FDI_t , GDS_t, MKC_t, NDC_t, NFA_t, ODA_t, PEQ_t, PRR_t and TCG_t with weights 0.1013, 0.0842, 0.2897, 0.1741, 0.0551, 0.0397, 0.0136, 0.1138 and 0.0025 respectively. These weights obtained in Chapter 5 are now combined with the significantly negative coefficients of the index of $lnKM_t$ for all the three types of the pollutions. In Table 6.3 and from equation 5.2, for example one-percent increase in foreign direct investment as a percentage of GDP (FDI_t) decreases air pollution by 3.33 percent (-0.3288*0.1013 = -0.0333), decreases water pollution by 2.66 percent (-0.2623*0.1013 = -0.0266) decreases land pollution by 2.12 percent (-0.2093*0.1013 = -0.0212) and increases GDP per capita (annual percentage growth) by 1.6 percent (0.1582*0.1013 = 0.0160) in the long-run. A decrease in all types of pollution and increase in GDP per capita is an indication and surety of good environmental conditions and strong economic growth in FDI recipient country that also has positive spillover effect on monetary assets. Similarly, Table 6.3 shows that one-percent increase in gross domestic savings as a percentage of GDP (GDS_t) decreases air pollution by 2.77 percent (-0.3288*0.0842 = -0.0277), decreases water pollution by 2.21 percent (-0.2623*0.0842 = -0.0221) decreases land pollution by 1.76 percent (-0.2093*0.0842 = -0.0176) and increases GDP per capita (annual percentage growth) by 1.33 percent (0.1582*0.0842 = 0.0133) in the long-run. A decrease in all types of pollution and increase in GDP per capita shows that a strong monetary sector generates financial resources by raising savings and distributes these resources to running investment and to set up new business that leads to environmental friendly infrastructure development that decreases pollution and increases GDP per capita.

Table 6.4

Estimation Results of Short-run ARDL Model with Conditional Error Correction Term

Dependent Variables	**Air Pollution ($\Delta lnEA_t$)**	**Water Pollution ($\Delta lnEW_t$)**	**Land Pollution ($\Delta lnET_t$)**	**Growth rate per Capita (ΔlnY_t)**
Dynamic Regressors	lnY_t, ΔlnY_t, $lnKM_t$, $\Delta lnKM_t$, $lnKP_t$, $\Delta lnKP_t$, lnL_t, ΔlnL_t, $lnEW_t$, $\Delta lnEW_t$, $lnET_t$, $\Delta lnET_t$	lnY_t, ΔlnY_t, $lnKM_t$, $\Delta lnKM_t$, $lnKP_t$, $\Delta lnKP_t$, lnL_t, ΔlnL_t, $lnEA_t$, $\Delta lnEA_t$, $lnET_t$, $\Delta lnET_t$	lnY_t, ΔlnY_t, $lnKM_t$, $\Delta lnKM_t$, $lnKP_t$, $\Delta lnKP_t$, lnL_t, ΔlnL_t, $lnEA_t$, $\Delta lnEA_t$, $lnEW_t$, $\Delta lnEW_t$	$lnKM_t$, $\Delta lnKM_t$, $lnKP_t$, $\Delta lnKP_t$, lnL_t, ΔlnL_t, $lnEA_t$, $\Delta lnEA_t$ $lnEW_t$, $\Delta lnEW_t$, $lnET_t$, $\Delta lnET_t$
Fixed Regressor	Unrestricted constant without trend			
Selected ARDL Model by SIC	(2,1,2,0,2,0,0)	(1,2,2,0,2,1,1)	(2,1,0,0,1,2,0)	(2,2,0,2,1,0,1)
C	28.8794***	2.7704***	0.5496***	12.0473***
(t-stats)	(10.5558)	(9.0589)	(7.3841)	(10.7548)
prob [t-stats]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
$\boldsymbol{\Delta lnY_t}$	0.3372***	0.2405***	0.2151***	-----
(t-stats)	(3.4704)	(6.1110)	(3.0493)	
prob [t-stats]	[0.0013]	[0.0003]	[0.0065]	
$\boldsymbol{\Delta lnKM_t}$	-0.2159***	-0.2068**	-0.1817***	0.1514***
(t-stats)	(-2.3451)	(-2.9419)	(-6.6668)	(3.6029)
prob [t-stats]	[0.0038]	[0.0373]	[0.0001]	[0.0057]
$\boldsymbol{\Delta lnKP_t}$	0.4322***	0.1766***	0.0993***	0.2123***
(t-stats)	(3.4159)	(5.6154)	(6.2722)	(4.6844)
prob [t-stats]	[0.0058]	[0.0002]	[0.0001]	[0.0007]
$\boldsymbol{\Delta lnL_t}$	-0.2922***	-0.3615***	-0.1378***	0.3938***
(t-stats)	(-6.0375)	(-12.1457)	(-4.0707)	(9.1556)
prob [t-stats]	[0.0001]	[0.0000]	[0.0037]	[0.0000]
$\boldsymbol{\Delta lnEA_t}$	-----	0.0228**	0.0455***	-0.0037***
(t-stats)		(5.7156)	(5.1507)	(-3.9265)
prob [t-stats]		[0.0346]	[0.0003]	[0.0059]
$\boldsymbol{\Delta lnEW_t}$	0.0919***	-----	0.0389***	-0.1389***
(t-stats)	(4.3842)		(5.5848)	(-6.1274)
prob [t-stats]	[0.0014]		[0.0005]	[0.0036]
$\boldsymbol{\Delta lnET_t}$	0.0624***	0.0266***	-----	-0.1925***
(t-stats)	(4.2831)	(3.9475)		(-3.5813)
prob [t-stats]	[0.0013]	[0.0043]		[0.0059]
$\boldsymbol{Cointegration\ term}$	-0.9602***	-0.7083***	-0.8228***	-0.3001***
(t-stats)	(-10.5548)	(-10.1693)	(-7.7774)	(-10.6953)
prob [t-stats]	[0.0000]	[0.0000]	[0.0000]	[0.0000]

Diagnostic Tests				
R^2	0.8985	0.9485	0.8028	0.9498
Adjusted R^2	0.8541	0.9154	0.7332	0.9095
F-Statistics	20.2406	28.6663	11.5377	29.9036
Prob[F-Statistics]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Schwarz Criterion	-2.7511	-4.8184	-7.4996	-8.5386
Breusch-Godfrey Serial Correlation LM Test				
Null Hypothesis of serial correlation in the residual up to two lags				
F-Stats	0.6411	4.6851	1.2494	2.7961
Prob [F-Stats]	[0.5517]	[0.1595]	[0.3320]	[0.1281]
n.R^2	3.3154	4.6312	5.2156	7.6584
Prob(2lags).Chi-square	[0.1906]	[0.1759]	[0.1737]	[0.4865]
Structure of Error Correction Terms (ECT_{t-1})				
Growth Model	$ECT_{t-1,Y} = lnY_t - (0.1582lnKM_t + 0.3323lnKP_t + 0.4535lnL_t - 0.0688lnEA_t - 0.1519lnEW_t - 0.2191lnET_t)$			
Air Pollution	$ECT_{t-1,EA} = lnEA_t - (0.3166lnY_t - 0.3288lnKM_t + 0.4169lnKP_t - 0.3181lnL_t + 0.2183lnEW_t + 0.0972lnET_t)$			
Water Pollution	$ECT_{t-1,EW} = lnEW_t - (0.2675lnY_t - 0.2623lnKM_t + 0.1335lnKP_t - 0.3923lnL_t + 0.0357lnEA_t + 0.0582lnET_t)$			
Land Pollution	$ECT_{t-1,ET} = lnET_t - (0.2243lnY_t - 0.2093lnKM_t + 0.0766lnKP_t - 0.1613lnL_t + 0.0568lnEA_t + 0.0426lnEW_t)$			

Note: (a). Sample size 1995 to 2022, Schwarz Information Criterion (SIC) is used as a model selection method, maximum dynamic regressors 2 lags (automatic selection).

(b). shows that Durbin Watson d-stats is not depicting autocorrelation in ARDL, so residual diagnostic test of Breusch-Godfrey Serial correlation LM Test is used.

(c). *, **, and *** represent 10%, 5% and 1% level of significance, respectively.

(d). For Symbols consider list of abbreviations.

In Table 6.4, a one-percent increase in gross domestic market capitalization of limited domestic companies as a percentage of GDP (MKC_t) decreases air pollution by 6.25 percent (-0.2159*0.2897 = -0.0625), decreases water pollution by 5.99 percent (-0.2068*0.2897 = -0.0599) decreases land pollution by 5.26 percent (-0.1817*0.2897 = -0.0526) and increases GDP per capita (annual percentage growth) by 4.39 percent (0.1514*0.2897 = 0.0439) in the short-run.

A decrease in all types of pollutions and increase in GDP per capita shows that licensing of limited domestic companies is conditional upon the step taken to decrease pollution. Increase in market capitalization of domestic companies definitely increases GDP per capita in domestic country. Similarly in Table 6.4, one-percent increase in net domestic credit (NDC_t) decreases air pollution by 3.76 percent (-0.2159*0.1741 = -0.0376), decreases water pollution by 3.6 percent (-0.2068*0.1741 = -0.0360) decreases land pollution by 3.16 percent (-0.1817*0.1741 = -0.0316) and increases GDP per capita (annual percentage growth) by 2.64

percent (0.1514*0.1741 = 0.0264) in the short-run. The elasticity of environmental degradation w.r.t NDC_t is more sensitive in case of air pollution and is less sensitive in case of land pollution. A decrease in all types of pollutions and increase in GDP per capita shows that net domestic credit is utilized to decrease pollutions and to increase investment. The existence of proper financial market in a country makes it as an attractive place for investment that expands MKC_t and NDC_t for that perceptible monetary hub and facilitates higher economic growth in future.

In Table 6.3, a one-percent increase in net foreign assets (NFA_t) decreases air pollution by 1.81 percent (-0.3288*0.0551 = -0.0181), decreases water pollution by 0.05 percent (-0.2623*0.0181 = -0.0005) decreases land pollution by 0.09 percent (-0.2093*0.0181 = -0.0009) and increases GDP per capita (annual percentage growth) by 0.02 percent (0.1514*0.0181 = 0.0002) in the long-run. The elasticity of environmental degradation through air pollution w.r.t net official development add received as a percentage of gross capital formation (ODA_t) is more elastic (-0.3288*0.0397 = - 0.0131) than the elasticity of environmental degradation through water (-0.2623*0.0397 = - 0.0104) and that of environmental degradation through land pollution (-0.2093*0.0397 = -0.0008). A one-percent increase in ODA_t increases GDP per capita (annual percentage growth) by 0.06 percent (0.1514*0.0397 = 0.0006). According to Maddison and Rehdanz (2008) high-income countries have aimed to aid developing countries in reducing negative climate change impacts via the establishment of the Green Climate Fund and financing technology (ODA_t). A decrease in all types of pollutions and increase in GDP per capita shows that net foreign assets and a net official development add received as a percentage of gross capital formation improves the financial stability of domestic country and hence decreases pollution and increases GDP per capita.

In Table 6.3, a one-percent increase in portfolio equity net inflows (PEQ_t) decreases air pollution by 0.045 percent (-0.3288*0.0136 = -0.00045), decreases water pollution by 0.036 percent (-0.2623*0.0136 = -0.00036) decreases land pollution by 0.028 percent (-0.2093*0.0136 = -0.00028) and increases GDP per capita (annual percentage growth) by 0.022 percent (0.1582*0.0136 = 0.000215). The elasticity of environmental degradation through air pollution w.r.t personal remittances received as a percentage of GDP (PRR_t) is more elastic (-0.3288*0.1138 = -0.0374) than the elasticity of environmental degradation through water (-0.2623*0.1138 = -0.0298) and that of environmental degradation through land pollution (-0.2093*0.1138 = -0.0272). A one-percent increase in PRR_t increases GDP per capita (annual percentage growth) by 1.8 percent (0.1582*0.1138 = 0.0180). A decrease in all types of pollution and increase in GDP per capita shows that portfolio equity net inflows, personal remittances received as a percentage of GDP and a technical corporation grants with large resource inflow serve the purpose of reducing environmental degradation and hence increases GDP per capita (Zafar et al., 2021).

In equation 5.2, the non-monetary or physical capital ($\mathrm{KP_t}$) is a weighted average of ($\mathrm{CIN_t}$), ($\mathrm{GCF_t}$), ($\mathrm{GVA_t}$), ($\mathrm{MHT_t}$), ($\mathrm{NIA_t}$) and ($\mathrm{RAD_t}$) with weights 0.1056, 0.1847, 0.0549, 0.3662, 0.1415 and 0.0229 respectively. These weights obtained in chapter 5 are now combined with the significantly positive coefficients of the index of ($\mathrm{KP_t}$) for all the three types of the pollutions. For example in Table 6.3 (above) a one-percent increase in changes in inventories ($\mathrm{CIN_t}$) increases air pollution by 4.4 percent (0.4169*0.1056 = 0.0440) increases water pollution by 10.56 percent 0.1335*0.1056 = 0.0141) increases land pollution by 0.081 percent (0.0766*0.1056 = 0.00081) and increases GDP per capita (annual percentage growth) by 3.51 percent (0.3323*0.1056 = 0.0351). Similarly in Table 6.3 (above), a one-percent increase in gross capital formation as a percentage of GDP ($\mathrm{GCF_t}$), increases air pollution by 7.7 percent (0.4169*0.1847 = 0.077), increases water pollution by 2.47 percent (0.1335*0.1847 = 0.0247), increases land pollution by 1.41 percent (0.0766*0.1847 = 0.0141) and increases GDP per capita (annual percentage growth) by 6.14 percent (0.3323*0.1847 = 0.0614). Also, a one-percent increase in gross value added $\mathrm{(GVA)_t}$ increases air pollution by 9.6 percent (1.9483*0.0493 = 0.0960), increases water pollution by 0.90 percent (0.1831*0.0493 = 0.0090) increases land pollution by 0.52 percent (0.1071*0.0493 = 0.0052) and increases GDP per capita (annual percentage growth) by 0.17 percent (0.0355*0.0493 = 0.0017). According to Sodersten et al., (2017) the investment in capital goods is a well-known driver of economic activity, associated resource use, and environmental impact. In national accounting, changes in inventories, gross capital formation as a percentage of GDP and gross value added constitute a substantial share of the total final demand of goods and services, both in terms of monetary turnover and physical resources. Sodersten et al., (2017) stated that countries in early phases of development generally tend to invest in resource-intensive assets, primarily infrastructure and machinery, whereas wealthier countries invest in less resource-intensive assets, such as computers, software, and services and hence affect environment with different intensities.

In Table 6.4, a one-percent increase in medium and high-tech industry (including construction) as a percentage of manufacturing value added (MHT_t), increases air pollution by 15.83 percent (0.4322*0.3662 = 0.1583), increases water pollution by 6.47 percent (0.1766*0.3662 = 0.0647) increases land pollution by 3.64 percent (0.0993*0.3662 = 0.0364) and increases GDP per capita (annual percentage growth) by 0.078 percent (0.2123*0.0366 = 0.00078) in the short-run. Similarly, a one-percent increase in net investment in nonfinancial assets as a percentage of GDP (NIA_t) increases air pollution by 6.12 percent (0.4322*0.1415 = 0.0612), increases water pollution by 2.49 percent (0.1766*0.1415 = 0.0249) increases land pollution by 1.41 percent (0.0993*0.1415 = 0.0141) and increases GDP per capita (annual percentage growth) by 3.01 percent (0.2123*0.1415 = 0.0301) in the short-run. Also a one-percent increase in research and development expenditure as a percentage of GDP (RAD_t) increases air pollution by 0.1 percent (0.4322*0.0229 = 0.001), increases water pollution by 0.04 percent (0.1766*0.0229 = 0.0004), increases land pollution by 0.02 percent (0.0993*0.0229 = 0.0002) and increases GDP per capita (annual percentage growth) by 0.05 percent (0.2123*0.0229 = 0.0005) in the short-run. Omri et al., (2022) stated that health expenditure and R&D expenditures can improve healthiness through reducing CO_2 emissions and environmental improvements.

The index of human capital (L_t) is a weighted average of (ADR_t), (CFW_t), (GEX_t), (GHE_t), (LFP_t), (POD_t), (SFM_t) and (TED_t) with weights -0.1348, 0.0934, 0.0598, 0.0827, 0.3242, -0.0063, 0.0818 and 0.0456. These weights obtained in chapter 5 are now combined with the significantly negative coefficients of the index of (L_t) for all the three types of the pollutions. For example, in Table 6.3 (above) a one-percent increase in total contributing family workers as a percentage of total employment (CFW_t) decreases air pollution by 2.97 percent (-0.3181*0.0934 = -0.0297), decreases water pollution by 3.66 percent (-0.3923*0.0934 = -0.0366), decreases land pollution by 1.51 percent (-0.1613*0.0934 = -0.0151) and increases GDP per capita (annual percentage growth) by 5.12 percent (0.2338*0.2194 = 0.0512) in the long-run. Similarly a one-percent increase in labor force participation rate as a percentage of total population ages 15+ (LFP_t) decreases air pollution by 10.31 percent (-0.3181*0.3242 = -0.1031), decreases water pollution by 12.72 percent (-

0.3923*0.3242 = -0.1272), decreases land pollution by 5.23 percent (-0.1613*0.3242 = -0.0523) and increases GDP per capita (annual percentage growth) by 14.7 percent (0.4535*0.3242 = 0.147) in the long-run. Also a one-percent increase in total self-employed as a percentage of total employment (SFM_t) decreases air pollution by 2.6 percent (-0.3181*0.0818 = -0.026), decreases water pollution by 3.21 percent (-0.3923*0.0818 = -0.0321), decreases land pollution by 1.32 percent (-0.1613*0.0818 = -0.0132) and increases GDP per capita (annual percentage growth) by 3.71 percent (0.4535*0.0818 = 0.0371) in the long-run. Also a one-percent increase in educational attainment at least completed short-cycle tertiary education for population ages 25+ as a percentage of total population (TED_t) decreases air pollution by 1.45 percent (-0.3181*0.0456 = -0.0145), decreases water pollution by 1.79 percent (-0.3923*0.0456= -0.0179), decreases land pollution by 0.07 percent (-0.1613*0.0456 = -0.0007) and increases GDP per capita (annual percentage growth) by 2.07 percent (0.4535*0.0456 = 0.0207) in the long-run.

In Table 6.4, a one-percent increase in government expenditure on education as a percentage of total government expenditure (GEX_t), decreases air pollution by 1.75 percent (-0.2922*0.0598 = -0.0175), decreases water pollution by 2.16 percent (-0.3615*0.0598 = -0.0216), decreases land pollution by 0.08 percent (-0.1378*0.0598 = 0.0008) and increase GDP per capita (annual percentage growth) by 2.35 percent (0.3938*0.0598 = -0.0235) in the short-run. Also a one-percent increase in domestic general government health expenditure per capita (GHE_t) decreases air pollution by 2.42 percent (-0.2922*0.0827 = -0.0242), decreases water pollution by 2.99 percent (-0.3615*0.0827 = -0.0299), decreases land pollution by 1.14 percent (-0.1378*0.0827 = 0.0114) and increases GDP per capita (annual percentage growth) by 3.26 percent (0.3938*0.0827 = 0.0326) in the short-run. Sultana et al., (2019) specified that the factors such as skills and competencies, formal education and knowledge (TED_t and GEX_t), health expenditure (GHE_t), organizational training, creativity and innovation capability, job experience (CFW_t, LFP_t, and SFM_t) have a positive and statistically significant impact on human capital formation through its productive roll and with a sense of awareness to decrease all types of pollutions. Specifically, an educated person through the practice of plantation mitigates all the three types of pollutions.

In Table 6.4, a one-percent increase in age dependency ratio as a percentage of working-age population ($\mathrm{ADR_t}$) increases air pollution by 3.94 percent (-0.2922*-0.1348 = 0.0394) increases water pollution by 14.96 percent (-0.3615*-0.4138 = 0.1496) increases land pollution by 5.7 percent (-0.1378*-0.4138 = 0.057) and decreases GDP per capita (annual percentage growth) by 16.29 percent (0.3938*-0.4138 = -0.1629) in the short-run. Similarly a one-percent increase in probability of dying among youth ages 20 to 24 years per one-thousand ($\mathrm{POD_t}$) increases air pollution by 0.18 percent (-0.2922*-0.0063 = 0.0018), increases water pollution by 0.23 percent (-0.3615*-0.0063 = 0.0023), increases land pollution by 0.09 percent (-0.1378*-0.0063 = 0.0009) and decreases GDP per capita (annual percentage growth) by 0.25 percent (0.3938*-0.0063 = -0.0025) in the short-run. Both these variables ($\mathrm{ARD_t}$ and $\mathrm{POD_t}$) have negative effects on labor productivity and hence on capital formation. The two-way causality implies that $\mathrm{POD_t}$ exist due to high rate of pollution. Stoler and Meltzer (2013) theorize that the high risk of mortality or morbidity in adulthood reduces investment in human capital formation. They further expounded that higher dependency ratio diminishes productive capacity and hence increases non-productive population leading to environmental degradation and adverse effects on economic growth.

The equation 5.4 expresses that the index of environmental degradation through air pollution ($\mathrm{EA_t}$) is a weighted average of ($\mathrm{ACF_{t_t}}$), ($\mathrm{C0E_t}$), (OGG_t), (MET_t), (NOE_t), and ($\mathrm{OGC_t}$) with weights -0.1638, 0.2874, 0.1341, 0.1177, 0.1525 and 0.0721 respectively. Now these weights (of chapter 5) are combined with the significantly positive coefficients of all the three types of the pollutions. For example, in Table 6.3 a one-percent increase in an access to clean fuels and technologies for cooking as a percentage of total population ($\mathrm{ACF_t}$) decreases water pollution by 0.58 percent (0.0357*-0.1638 = -0.0058), decreases land pollution by 0.93 percent (0.0568*-0.1638 = -0.0093) and increases GDP per capita (annual percentage growth) by 1.13 percent (-0.0688*-0.1638 = 0.0113) in the long-run. A negative impact of $\mathrm{ACF_t}$ help to reduce the deterioration of air, water and land quality through less dependence on traditional cooking methods of wood and coal burning.

In Table 6.4, a one-percent increase in $\mathrm{CO_2}$ emissions, metric tons per capita ($\mathrm{COE_t}$) increases water pollution by 0.65 percent (0.0228*0.2874 = 0.0065), increases land pollution by 1.31 percent (0.0455*0.2874 = 0.0131) and decreases GDP per capita (annual percentage growth) by 0.11 percent (-0.0037*0.2874 = -0.0011) in the short-run. Similarly a one-percent increase in greenhouse gas emissions (OGG_t) i.e., HFC, PFC and SF6 thousand metric tons of CO_2 equivalent increases water pollution by 0.31 percent (0.0228*0.1341 = 0.0031), increases land pollution by 0.61 percent (0.0455*0.1341 = 0.0061) and decreases GDP per capita (annual percentage growth) by 0.05 percent (-0.0037*0.1341 = -0.0005) in the short-run. Also a one-percent increase in methane emissions kiloton of CO_2 equivalent (MET_t) increases water pollution by 2.68 percent (0.0228*0.1177 = 0.0268), increases land pollution by 0.54 percent (0.0455*0.1177 = 0.0054) and decreases GDP per capita (annual percentage growth) by 0.04 percent (-0.0037*0.1177 = -0.0004) in the short-run. A one percent increase in nitrous oxide emissions in energy sector as a percentage of total emissions (NOE_t) increases water pollution by 0.35 percent (0.0228*0.1525 = 0.0035) increases land pollution by 0.69 percent (0.0455*0.1525 = 0.0069) and decreases GDP per capita (annual percentage growth) by 0.06 percent (-0.0037*0.1525 = -0.0006). A one-percent increase in electricity production from oil, gas and coal sources as a percentage of total electricity production (OGC_t) increases water pollution by 0.16 percent (0.0228*0.0721 = 0.0016), increases land pollution by 0.33 percent (0.0455*0.0721 = 0.0033) and decreases GDP per capita (annual percentage growth) by 0.027 percent (-0.0037*0.0721 = -0.00027) short-run.

The equation 5.5 shows that in the index of environmental degradation through water pollution (EW_t), all the components (i.e., BSS_t, FWR_t and SMW_t) have negative role in infuriating water pollution. In Table 5.4, an increase in the people using at least basic sanitation services as a percentage of total population (BSS_t), renewable internal freshwater resources per capita (FWR_t) and people using safely managed drinking water services as a percentage of total population (SMW_t) are environment friendly services that help to reduce water pollution and thus have negative loading scores (-0.2854, -0.2575 and -0.1088 respectively). For example in Table 6.3 (above) a one-percent increase in BSS_t decreases air pollution by 3.66 percent (0.1283*-0.2854 = -0.0366), decreases land pollution by 1.22 percent (0.0426*-0.2854 = -0.0122) and increases GDP per capita (annual percentage growth) by 4.34 percent (-0.1519*-0.2854 = 0.0434) in the long-run. Similarly, in Table 6.4 (above) a one-percent increase in FWR_t decreases air pollution by 2.37 percent (0.0919*-0.2575 = -0.0237), decreases land pollution by 1.001 percent (0.0389*-0.2575 = -0.01001) and increases GDP per capita (annual percentage growth) by 3.58 percent (-0.1389*-0.2575 = -0.0358) in the short-run. Also, a one-percent increase in SMW_t decreases air pollution by 0.99 percent (0.0919*-0.1088 = -0.0099), decreases land pollution by 0.42 percent (0.0389*-

0.1088 = -0.0042) and increases GDP per capita (annual percentage growth) by 1.51 percent (-0.1389*-0.1088 = 0.0151) in the short-run. In case of water pollution, container port traffic (CPT_t) has positive weights (loading, 0.1618) and hence CPT_t increases the water pollution at steam, rivers and sea shores. A one-percent increase in CPT_t increases air pollution by 1.49 percent (0.0919*0.1618 = 0.0149), increases land pollution by 0.63 percent (0.0389*0.1618 = 0.0063) and decreases GDP per capita (annual percentage growth) by 0.22 percent (-0.1389*0.1618 = -0.0022) in the short-run.

The equation 5.6 shows that in the index of environmental degradation through land pollution (ET_t), all the components (i.e., AME_t, ANE_t, FCN_t, ODE_t, OMX_t, PDN_t and URP_t have positive weights (0.0349, 0.0425, 0.1534, 0.1325, 0.0536, 0.1811 and 0.0728) indicating that an increase in them aggravates the land pollution. For example, from Table 6.3 a one-percent increase in agricultural methane emissions percentage of total emission (AME_t) increases air pollution by 0.34 percent (0.0972*0.0349 = 0.0034), increases water pollution by 0.2 percent (0.0582*0.0349 = 0.002) and decreases GDP per capita (annual percentage growth) by 0.76 percent (-0.2191*0.0349 = -0.0076) in the long-run. Similarly, a one-percent increase in agricultural nitrous oxide emissions percentage of total emissions (ANE_t) increases air pollution by 0.41 percent (0.0972*0.0425 = 0.0041), increases water pollution by 0.25 percent (0.0582*0.0425 = 0.0025) and decreases GDP per capita (annual percentage growth) by 0.93 percent (-0.2191*0.0425 = -0.0093) in the long-run. Also a one-percent increase in employment fertilizer consumption, kilograms per hectare of arable land (FCN_t) increases air pollution by 1.49 percent (0.0972*0.1534 = 0.0149), increases water pollution by 0.89 percent (0.0582*0.1534 = 0.0089) and decreases GDP per capita (annual percentage growth) by 3.36 percent (-0.2191*0.1534 = -0.0336) in the long-run.

In Table 6.4 a one-percent increase in people practicing open defecation (percentage of population) i.e., ODE_t increases air pollution by 0.83 percent (0.0624*0.1325 = 0.0083), increases water pollution by 0.35 percent (0.0266*0.1325 = 0.0035) and decreases GDP per capita (annual percentage growth) by 2.55 percent (-0.1925*0.1325 = -0.0255) in the short-run. A one percent increase in ores and metals exports as a percentage of merchandise exports (OMX_t) increases air pollution by 0.33 percent (0.0624*0.0536 = 0.0033), increases water pollution by 0.14 percent (0.0266*0.0536 = 0.0014) and decreases GDP per capita (annual percentage growth) by 1.03 percent (-0.1925*0.0536 = -0.0103) in the short-run. A one-percent increase in population density that are people per square km of land area (PDN_t) increases air pollution by 1.13 percent (0.0624*0.1811 = 0.0113), increases water pollution by 0.48 percent (0.0266*0.1811 = 0.0048) and decreases GDP per capita (annual percentage growth) by 3.49 percent (-0.1925*0.1811 = -0.0349) in the short-run. A one-percent increase in urban population as a percentage of total population (URP_t) increases air pollution by 0.45 percent (0.0624*0.0728 = 0.0045), increases water pollution by 0.19 percent (0.0266*0.0728 = 0.0019) and decreases GDP per capita (annual percentage growth) by 1.4 percent (-0.1925*0.0728 = -0.014) in the short-run.

In Table 6.3 and from equation 5.6, an increase in permanent cropland as a percentage of land area (CLA_t) helps to decrease the land pollution. A one percent increase CLA_t decreases air pollution by 1.01 percent (0.0972*-0.1039 = -0.0101), decreases water pollution by 0.6 percent (0.0582*-0.1039 = -0.006) and increases GDP per capita (annual percentage growth) by 2.28 percent (-0.2191*-0.1039 = 0.0228) in the long-run. Bai et al., (2020) examined the impact of agglomeration factors (i.e., educational attainment, non-agricultural employment rate, disaster rate, and farmers' income) on fertilizer-use-efficiency and thus on environmental contamination. A one-percent increase in employment in agriculture as a percentage of total employment (EAS_t) decreases air pollution by 1.29 percent (0.0972*-0.1324 = -0.0129), decreases water pollution by 0.77 percent (0.0582*-0.1324 = -0.0077) and increases GDP per capita (annual percentage growth) by 2.9 percent (-0.2191*-0.1324 = 0.029) in the long-run.

In Table 6.3 the estimation results of long-run ARDL model without conditional error correction term and in Table 6.4 the estimation results of short-run ARDL model with error correction term are presented. Indeed, the error correction mechanism developed by Engle and Granger is a means of reconciling the short-run behavior of an economic variable (index) with its long-run behavior, as is determined by the equal magnitude of the short-run coefficients in Table 6.4 for results of ARDL model with and without error correction term. Similarly, the signs and the magnitudes long-run co-integrating coefficients of different indices presented in Table 6.3 are compatible with the coefficients presented in Table 6.4 and with old empirical literature reviewed in chapter 2. Conveniently the interpretation of the long-run co-integrating coefficients in Table 6.3 holds for short-run co-integrating coefficients Table 6.4 with minor changes.

The novelty in Table 6.4 is that of introduction of error correction term (ECT_{t-1}). The existence of co-integration is supported by the statistically significant negative values of ECT_{t-1} in these models. Since ECT_{t-1} measures the speed of adjustment i.e., how quickly the short-run shocks can be corrected toward the long-run equilibrium levels. The negative, less than one percent significant values of ECT_{t-1} indicate that the short-run shocks are rapidly adjusting to the long-run equilibrium for of all types of environmental degradation and for economic growth. A negative significant value is a requirement for convergence and less than one percent value indicate that "less" than hundred percent adjustments is possible. The structure of error correction term is provided in the lower portion of Table 6.4.

CHAPTER 7

CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 The Conclusions

The study focuses on the three sources of pollution, specifically air, water and land pollution, and estimates the relationship between environmental degradation and economic growth through the instruments of Cobb Douglas production function and environmental Kuznets curve over the years 1995 till 2022. The study is concluded on analytical evidence for each of its objective.

The first objective of this study is to identify the factors responsible for the air, water and land pollution in addition to traditional carbon emissions. In the index of air pollution (EA_t) the access to clean fuels and technologies for cooking as a percentage of total population (ACF_t) has negative loading showing that ACF_t help to decrease deterioration of air quality through less reliance on traditional cooking methods of wood and coal burning. Whereas, open fire cooking ignites environmental issues of air pollution. In the index of EW_t an increase in the usage of at least basic sanitation services as a percentage of total population (BSS_t), renewable internal freshwater resources per capita (FWR_t) and people using safely managed drinking water services as a percentage of total population (SMW_t) are environment friendly services that help to reduce water pollution. Whereas container port traffic (CPT_t) with positive weights increases the water pollution at steam, rivers and sea shores. Finally, in the index of ET_t the increase in permanent cropland as a percentage of land area (CLA_t) helps to decrease the land pollution. The effect of chemical fertilizers as an input in crop production depletes the environment and ecosystem.

The second objective is to justify environment-economy nexus through an empirical analysis to determine the magnitude of the effect of chauffeurs of air, water and land pollution, besides physical capital and human capital on economic growth of Pakistan. In double-log-form of ARDL model the coefficients of the explanatory variables (indices) are representative of the elasticities. A decrease in all types of pollution and increase in GDP per capita w.r.t FDI_t is an indication of strong economic growth in FDI recipient country. The negative elasticity of all types of pollution and positive elasticity of GDP per capita w.r.t GDS_t show that a strong financial sector that through increased savings increase investment that promote environment-friendly infrastructure development and in return decreases pollution and increases GDP per capita. The elasticity of environmental degradation through air pollution w.r.t ODA_t is in accordance to the establishment of the Green Climate Fund for financing technology that aims to aid developing countries in reducing climate change adversities. The negative elasticities of all types of pollution and positive elasticities of GDP per capita w.r.t PEQ_t, PRR_t, and TCG_t with large resource inflows serve the purpose of reducing environmental degradation and in return increase GDP per capita.

The negative elasticities of all types of pollution and a positive elasticity of GDP per capita w.r.t CIN_t, GCF_t, and GVA_t show that in national income accounting all these variables contributes to environment-friendly increase in final goods and services both in terms of monetary turnover and physical resources. An increase in CFW_t, in LFP_t, in SFM_t, in TED_t, in GEX_t, in GHE_t have a positive and statistically significant impact on human capital formation through increase in its productivity and with a sense of awareness to decrease all types of pollutions. An increase in COE_t, in OGG_t, MET_t, in NOE_t, in OGC_t increases air, water, and land pollution and decreases GDP per capita. The BSS_t, FWR_t, and SMW_t are environment friendly services that help to reduce air, water and land pollution. In the index of environmental degradation through land pollution an increase in AME_t, in ANE_t, in FCN_t, in ODE_t, in OMX_t, in PDN_t, and in URP_t worsen the air, water, and land pollution and decreases GDP per capita.

The third objective is to test the validity of environmental Kuznet curve hypothesis separately for each type of pollution. The positive coefficients of lnY_t and ΔlnY_t are the long-run and the short-run elasticities of air pollution, water pollution and land pollution, indicating that all the three type of pollutions increases in early stage of economic growth and development. The insignificant elasticities of air pollution, water pollution and land pollution wr.t lnY_t^2 and lnY_t^3 indicate that all the three type of pollutions are not affected by second and third stages of economic growth and development that are noot yet achieved by Pakistan. In short, the polynomial inverted U-shaped or N-shapted environmental Kuznets curve not holds for Pakistan. Instead, a linear environmental Kuznets curve truly depicts the initial stages of economic growth and development in Pakistan.

7.2 Policy Recommendations

According to the Global Climate Risk Index, Pakistan ranked as the eighth-most vulnerable country to climate change (2022). One of the conclusions of present study is that quadratic (inverted U-shaped) or cubic (N-shaped) environmental Kuznets curve do not exist in Pakistan. Though Pakistan has low greenhouse gas emissions, yet it may increase significantly as the country develops and strives to provide sufficient amounts of energy to support its growing developmental needs. Therefore, the positively sloped environmental Kuznets curve is of alarming concern for Pakistan. The present study through the process of index formation provides composition of three types of pollutions that can be controlled by keeping an eye on their determinants. As the responsibility to protect the environment and its resources rests with all stakeholders, including the public and private sectors as well as individuals, therefore in general policy makers can minimize environmental degradation by encouraging the use of environmental-friendly equipment, machinery, vehicles, and utilities. The private sector plays its role through awareness campaigns, cleaning drives, and WASH programs. In addition, individual should avoid careless household and municipal waste disposal, overexploitation of forests and extensive and unsustainable water consumption. In general, to protect the environment and its resources the following policy recommendations are suggested;

First: Environment is a global asset. An atmosphere covering Pakistan is not separated from rest of the globe. So MoCC (ministry of climate change and environmental coordination) expands its role to protect environment via international collaboration. MoCC in partnership with CAA (clean air Asia) and SEI (Stockholm environment institute) is already providing training on the use of LEAP (low emission analysis platform) including IBC (integrated benefits calculators). Thus, to identify and mitigate the air, water and soil pollution, MoCC should search out international assistance beside CAA, SEI, and Global methane pledge.

Second: Just like CGPI (clean green Pakistan index) MoCC in collaboration with PBS (Pakistan Bureau of Statistics) should help in tracking, reporting, monitoring and evaluation of SDGs (sustainable development goals) that help to save air, land and water. The MoCC's sponsored project for per capita WASH (water, sanitation and hygiene) and HH4A (hand hygiene for all) beside KOICA (Korea International coorporation agency) grant are good opportunities to have healthy and clean environment in Pakistan. MoCC may play its role to track and monitor the performance of SDG indicators effectively.

Third: 80% of Pakistan's population is living on the Indus Basin. MoCC with help food and agriculture organization of United Nation can ecologically restore Indus basin for a climate resilient future.

Fourth: Like Astola Island, a first marine protected area of Pakistan MoCC with other ministries (defense, maritime affairs etc) can work to increase marine protected areas in the country.

Fifth: Along funding and plantation for TBTTP (ten billion tree tsunami programme), MoCC may help geographic information center (GIS) team of TBTTP in web-GIS monitoring portal which is capable to visualize the plantation sites geographically with detailed information of the site and processed satellite imagery of pre and post plantation status.

Sixth: Beside environment monitoring, MoCC in collaboration with NAVTTC (national vocational & technical training commission) can make billion tree honey initiative more successful by providing training to the selected beekeepers along with technical support, follow-up of on-ground activities and product extraction. MoCC may corresponds to ministry of science and technology to certify the honey products under the programme, and may ask the ministry of commerce to patent the market brand of "ten billion tree honey". In this way MoCC beside environmental protection can help to achieve high growth.

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Appendix-A

Literature Review

STUDY/YEAR	COUNTRY	PERIOD OF ANALYSIS/ DATA SOURCES	ESTIMATION TECHNIQUE USED	RESULTS
2.2.1 Empirical Literature on Determinants of Air Pollution				
Khan et al., (2020)	Pakistan	annual time series data (1965 to 2015)	ARDL bound test	• positive effect of energy consumption& economic growth on CO_2 emission
Dickinson et al., (2015)	Ghana	survey data from 200 household	pollution source sampling	• cooking over open fires ignites environmental issues • measure spatial & temporal variability of air pollution & identify pollutant sources as trash burning, different types of commercial cooking, & vehicle emissions
Jalil & Mahmud (2009)	China	time series data from 1975 till 2005	ARDL model	• carbon emissions determined by income & energy consumption • quadratic relationship b/w income & CO_2 emission
2.2.2 Empirical Literature on Effect of Air Pollution on Economic Growth				
Tenaw (2021)	Ethiopia	annual data from 1975 till 2017	ARDL model and Toda-Yamamoto Granger causality test	• scale effect of growth increases GHG emission (CO_2, CH_4 & N_2O)
Yousuf et al., (2020)	African OPEC countries	annual data from 1970 through 2016	panel ARDL model	• non-linear relationship b/w methane emission & economic growth
Işık et al. (2019)	10 US States	annual data from 1980 through 2015	panel estimation method with cross-sectional dependence	• an inverted U-shaped EKC hypothesis is valid for the states of Florida, Illinois, Michigan, New York and Ohio
Zaidi & Fehri (2019)	Sub-Saharan countries	annual data from 2000 through 2012	dynamic simultaneous-equation	• a bidirectional causal relationship b/w energy consumption & economic growth
Davis (2012)	California USA	annual data from 1980 through 2000	Correlation analysis	• positive correlation b/w economic expansion (contraction) and increased (reduced) pollution
2.3.1 Empirical Literature on Determinants of Water Pollution				
Templeton et al., (2015)	3 West African cities	Cross-sectional data for the year 2014	Site visits	• in areas with a near-surface aquifer, the potential for nitrate pollution arising from pit latrines is worrisome
Khatri and Tyagi (2014)	India	Cross-sectional data for the year 2013	Site visits	• in rural and urban areas of developing countries, ground and surface water is affected by natural and biological processes • anthropogenic factors affecting water quality include impacts of agriculture, use of fertilizers, manures and pesticides, animal husbandry activities, inefficient irrigation practices, deforestation of woods, aquaculture, pollution due to industrial effluents& domestic sewage, mining, & recreational activities

2.3.2 Empirical Literature on Effect of water Pollution on Economic Growth				
Sheikh & Hassan (2020)	15 districts of Uttar Pradesh (India)	annual data from 2001 through 2018	Panel unit root tests, Pedroni co-integration test & FMOLS	• no evidence of an EKC for biochemical oxygen demand • results validate the presence of an EKC for total coliform
Choi et al., (2015)	4 rivers of South Korea	Cross sectional data for the year 2014 and 2015	Breusch-Pagan test (for heteroscedasticity), Durbin-Watson test for autocorrelation), Wu-Hausman test (for endogeneity) & OLS	• assessed relationship b/w economic growth and water quality indicators • turning point for improved water quality occurred at later economic development stages for industrial pollution than for biological pollution
Paudel et al., (2005)	24 Louisiana parishes	panel data for 14 years ranging from 1985 through 1998	fixed-effects parametric specification & flexible semiparametric specification	• instead of parametric models flexible semiparametric specification is more flexible to test the relationship between environmental quality & income • out of nitrogen, phosphorus, and dissolved oxygen EKC holds only for nitrogen
2.4.1 Empirical Literature on Determinants of Land Pollution				
Zhang and Wang (2020)	Comparative study of South and North China	selected year-wise analysis from 1990 till 2016	Comparative analysis	• human factors responsible for land pollution are mining, abandoned mining areas, intensive application of fertilizer and pesticide, and sewage irrigation
Bai et al., (2020)	31 provinces of China	selected year-wise analysis from 2007 through 2017	stochastic frontier method and geographical weighted regression model	• examine the impact of agglomeration factors namely improvement in educational level, non-agricultural employment ratio, disaster ratio, and farmers' income on fertilizer use efficiency and hence on environmental contamination
Chandhni et. al., (2019)	India	1998/1999	review of existing literature	• fertilizer used as an input in crop production depletes the environment & ecosystem by depleting the natural resources & by threatening the life on earth
2.4.2 Empirical Literature on Effect of Land Pollution on Economic Growth				
Ajanaku & Collin (2020)	Africa 30 countries	annual data from 1972 through 2014	panel unit root & panel co-integration tests	• explore the impacts of changing structure of economies, land degradation, soil erosion, bio-energy consumption, and demographic factors on net deforestation • confirm the validity of EKC hypothesis for net deforestation
Cuaresma et al., (2017)	National borders across countries	annual satellite data from 2016 through 2017	homogeneous response units & vegetation continuous fields	• per capita income a robust determinant of differences in cross-border forest cover • strongest evidence for the existence of an EKC for deforestation
Lal (2010)	*Columbus*, Ohio, USA	qualitative data collected through survey	experimental & geo-statistics techniques	• The available database on the global impacts of erosion on productivity is weak, sketchy, and inconsistent.

Source: Author.

Appendix-B

Pair-Wise Correlation Matrix between the Drivers of Monetary, Physical and Human Capital

	ADR_t	CFW_t	CIN_t	FDI_t	GCF_t	GDS_t	GEX_t	GHE_t	GVA_t	LFP_t	MHT_t	MKC_t	NDC_t	NFA_t	NIA_t	ODA_t	PEQ_t	POD_t	PRR_t	RAD_t	SFM_t	TCG_t	TED_t
ADR_t	1.000																						
CFW_t	-0.09	1.000																					
CIN_t	0.337	**0.888**	1.000																				
FDI_t	**0.981**	0.456	0.366	1.000																			
GCF_t	-0.43	**0.876**	-0.05	0.123	1.000																		
GDS_t	**0.888**	-0.09	0.009	-0.06	0.028	1.000																	
GEX_t	0.217	0.024	**0.811**	0.007	-0.02	0.032	1.000																
GHE_t	0.305	0.431	**0.981**	0.063	0.021	0.057	0.097	1.000															
GVA_t	-0.31	**0.945**	0.072	0.003	0.074	0.129	-0.07	-0.07	1.000														
LFP_t	-0.02	0.683	**0.838**	0.071	0.009	-0.07	0.009	0.197	0.321	1.000													
MHT_t	0.214	**0.878**	0.098	0.098	-0.21	0.043	0.204	0.363	-0.09	0.019	1.000												
MKC_t	**0.879**	0.451	0.067	-0.39	0.001	0.054	**-0.92**	0.099	0.008	0.068	0.087	1.000											
NDC_t	**0.987**	-0.32	0.054	0.106	**0.792**	0.321	-0.14	0.084	**-0.98**	0.325	0.137	**0.987**	1.000										
NFA_t	**0.867**	0.156	-0.06	0.207	0.004	0.076	0.432	0.218	0.341	0.087	0.293	-0.08	0.092	1.000									
NIA_t	0.357	**0.866**	0.032	-0.34	0.053	0.541	0.067	0.179	0.174	0.098	0.097	0.257	0.328	0.009	1.000								
ODA_t	**0.981**	0.278	0.016	**0.768**	0.012	0.078	0.054	-0.07	0.293	0.215	0.125	0.365	0.546	0.045	0.345	1.000							
PEQ_t	**0.931**	0.015	0.073	0.572	0.065	0.238	0.571	**0.897**	0.054	0.376	-0.06	0.087	-0.07	-0.09	-0.07	0.009	1.000						
POD_t	-0.34	-0.07	**-0.82**	0.981	0.039	0.168	-0.02	0.541	0.158	0.548	**-0.74**	0.421	**-0.78**	0.003	-0.23	**0.977**	0.009	1.000					
PRR_t	**0.821**	0.054	0.081	0.761	-0.04	-0.09	0.084	0.076	0.292	**0.981**	0.087	0.098	0.256	0.541	0.016	-0.08	0.098	0.176	1.000				
RAD_t	-0.14	**0.844**	-0.09	0.054	0.234	-0.02	0.328	0.057	0.196	-0.06	0.231	-0.08	0.076	0.098	**0.754**	0.017	**-0.87**	-0.08	0.099	1.000			
SFM_t	0.203	0.093	**0.889**	0.361	0.368	**0.987**	0.009	0.093	0.085	-0.03	0.067	-0.07	0.329	0.078	0.007	-0.04	0.076	0.281	0.188	0.098	1.000		
TCG_t	**0.843**	-0.05	0.048	-0.22	-0.09	0.091	0.045	0.054	0.092	0.076	0.321	-0.02	0.218	0.329	0.043	0.009	0.054	0.345	-0.04	-0.07	0.097	1.000	
TED_t	-0.16	0.065	**0.988**	0.185	0.063	-0.04	-0.87	0.026	0.176	0.234	0.056	0.093	0.945	0.076	0.154	0.006	0.435	-0.02	0.009	-0.02	0.218	0.342	1.000

Notes: E-Views output for Pair-wise Correlation Matrix.
For Symbols consider list of abbreviations.

Appendix-C

Pair-Wise Correlation Matrix between the Determinants of Environmental Degradation

	ACF_t	AME_t	ANE_t	BSS_t	CLA_t	COE_t	CPT_t	EAS_t	FCN_t	FWR_t	OGG_t	MET_t	NOE_t	ODE_t	OGC_t	OMX_t	PDN_t	SMW_t	URP_t
ACF_t	1.000																		
AME_t	0.431	1.000																	
ANE_t	0.073	0.007	1.000																
BSS_t	0.275	**-0.989**	0.007	1.000															
CLA_t	0.009	0.061	**-0.89**	0.304	1.000														
COE_t	**0.832**	0.321	0.062	0.056	0.341	1.000													
CPT_t	-0.03	**0.811**	0.009	0.215	0.123	0.021	1.000												
EAS_t	0.019	0.003	**-0.85**	0.432	0.355	0.009	0.345	1.000											
FCN_t	0.304	-0.05	**0.843**	0.072	0.367	**-0.78**	0.097	0.048	1.000										
FWR_t	0.279	**-0.234**	0.121	0.011	**0.789**	0.347	-0.08	**-0.98**	0.234	1.000									
OGG_t	**0.912**	0.167	-0.05	0.006	0.098	0.043	-0.09	0.129	0.056	0.091	1.000								
MET_t	**0.892**	0.345	0.003	**-0.87**	0.076	0.234	0.054	0.387	0.008	0.209	0.009	1.000							
NOE_t	**0.854**	0.391	0.066	0.513	0.009	0.403	**0.796**	0.215	0.009	0.056	0.241	0.324	1.000						
ODE_t	0.006	0.209	**0.954**	0.305	0.082	0.008	0.033	**0.774**	**0.897**	0.021	**0.987**	0.087	-0.32	1.000					
OGC_t	**0.786**	0.008	0.043	**0.879**	0.032	-0.08	0.409	0.098	0.074	0.001	-0.08	-0.043	-0.034	-0.23	1.000				
OMX_t	0.054	0.041	**0.865**	0.015	0.144	0.345	**0.876**	0.143	0.034	0.008	-0.09	-0.098	**0.987**	0.009	-0.08	1.000			
PDN_t	0.169	0.117	**0.877**	0.009	**-0.79**	0.549	0.198	0.309	0.165	**-0.876**	0.024	**-0.789**	0.008	0.002	-0.12	0.435	1.000		
SMW_t	0.298	**-0.828**	0.009	0.451	0.008	**0.798**	0.009	0.133	0.287	0.123	0.043	0.033	0.003	0.321	0.096	-0.081	-0.012	1.000	
URP_t	-0.03	0.001	**0.977**	0.231	0.019	0.009	0.081	0.378	0.365	0.345	0.435	0.044	0.123	0.543	0.067	0.417	0.345	0.034	1.000

Notes: E-Views Output for Pair-wise Correlation Matrix.
For Symbols consider list of abbreviations.