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Environmental Kuznets Curve and SO_2 Emission in Pakistan

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Abstract: In this study, the Environmental Kuznets Curve (EKC) is hypothesized to examine the connection among SO_2 emission, economic growth, trade liberalization, energy consumption and population density in Pakistan with annual data from 1970-2008. The co integration analysis using Auto Regressive Distributed Lag (ARDL) bounds testing approach is used. The outcomes support the hypothesis both in short-run and long-run and inverted U shaped relationship is found between SO_2 emission and growth. Interestingly we found trade support the environment positively and population contributes to environmental degradation in Pakistan. The energy consumption and growth are the major explanatory variables which contribute to environmental pollution in Pakistan. Moreover, the time series data analysis is utilized and the stability of variables in estimated model is also evaluated.

Keywords: Auto Regressive, Distributed Lag (ARDL), Environmental Kuznets Curve (ECK), environmental degradation, SO_2

INTRODUCTION

One of the major concerns arising around the globe is the climate change. Climate change is an established fact that adversely influences our environmental sectors like water, agriculture, health, biodiversity, forests and socio-economic fields. The term climate change is referred to as "The change in our global environment or weather because of some natural or anthropogenic activities sustaining for a longer span of time" intergovernmental panel on climate change (IPCC, 2007). According to IPCC (2007), climate change would be suffered more adversely by the developing or least developed countries than the developed ones. This can be understood in better way when we scale down this fact to the community or individual levels (Ansari, 2002). Lesser accessibility to resources makes poor communities to face more severe consequences whenever any climatic anomaly happens or occurs. It is widely believed that the surging trends of climate related disasters occurring in various parts of the earth are mainly because of anthropogenic activities and people having marginal incomes are the major sufferers of such catastrophic disasters. Recorded global temperature during 20th century was 0.76 centigrade which is now increased by 0.6° only during first decade of 21st century.

In order to sustain surface of Earth, some of the radiant solar warmth is detained in Earth's lower atmosphere by natural process called "The Greenhouse Effect". Those gases assist to sustain solar heat are called "Green house Gases"(GHG) containing methane, carbon dioxide, nitrous oxide, water vapors and variety of prepared chemicals. Some of these are released from natural resources while others are by human activities. Emissions of Green House Gases (GHGs) have been drastically increased to our environment by our industries and the burning of fossil fuels after the industrial revolution. GHGs are potentially playing the major roll in global warming on a sustainable and continuous warming process over centuries.

Pakistan has adverse climate condition that why Pakistan is one of the most vulnerable country on Earth. Temperature increase is anticipated to be higher than the world average temperature increase in the geographical region in which Pakistan exists. Land area is generally arid and semi-arid (about 60% of its area have less than 250 mm of precipitation annually and 24% have in between 250-500 mm). Pakistan's rivers predominantly get water from Hindukush Karakoram Himaliyan (HKH) glaciers due to global warming, are receding rapidly. Financial system of Pakistan is mostly based on agriculture hence highly climate responsive. This puts in Pakistan in facing higher threat of inconsistency in monsoon precipitation resulting in heavy flood and droughts. Pakistan's water, food and energy is now under serious threat that influenced by all these factors. Rising cyclonic activity, salty sea water interference, coastal erosion and Sea level rise in the Arabian Sea are compounding these problems exposing the coastal areas and Indus deltaic region to the higher risks. Any rise in the temperature of Indus delta would affect human physical condition due to vector borne diseases, cholera, heat strokes and diarrhea and because

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this region already has high level of temperature. Also frequent floods, droughts and cyclones will adversely affecting human settlements (Robert *et al*., 2009). Temperature is expected to rise up to 4 centigrade by year 2100 in this region and rain is going to be extremely changeable on spatial and temporal scale. Local weather conditions as well as weather conditions upstream ocean Indus and in the nearest ocean in the south will affect this Deltaic region the most due to climate change.

High level toxic gases (CO_2, SO_2 and NO_x) in our atmosphere are the direct cause of global warming issue while GHGs contain the sun rays in our atmosphere by not letting them escape back into upper space. GHGs particularly CO_2 created by human activities collectively increase absorption of GHGs in the environment causing more light to be trapped and rise in temperature of Earth (Brown 1998). Some of the consequence of the worldwide hotness can be observed in the form of rise in sea level, newly born diseases, non-supporting weather conditions, food shortage, more frequent drought and floods etc (Tisdell, 2008). Anthropogenic activities and deforestation are most likely the ways which are mounting the concentration of GHGs in our atmosphere. Environmentalists believe that till year 2100 this concentration would more likely to be raised up to 3 times more than the pre-industrial era that may consequently resulting into "hike of earth" temperature by 3 to 10°.

Breathing problems like asthmatic conditions will tend to increase in the children and individuals which are exposed to environment directly because of increased concentration of sulfur dioxide (SO_2). Some of the asthmatic conditions can more likely be wheezing, chest tightness and shortness of breath which may be caused by short term exposure. While continuous or long term contact to SO_2 in combination with high stages of particulate soot may result to the diseases like respiratory illness, alteration in the lungs and aggravation of existing cardiovascular problems. Acid rains are responsible for the acidity of soil, lakes, streams, acceleration corrosions of buildings/monuments and reduced visibility is majorly caused by Sulfur dioxide and Nitrogen oxide. Sulfur dioxide SO_2 also is a main originator of fine particulate soot, which creates a major health risk.

In this study, attempt to discover the relationship among the economic growth and environmental degradation caused by SO_2 in case of Pakistan. This study is significantly different from previous studies because it will collectively check the impact of SO_2 on growth. This study is undertaken in order to comprehensively test the hypothesis of Environmental Kuznets Curve for both long run and short run in presence of energy consumption, trade openness, economic growth and more especially population growth rate.

LITERATURE REVIEW

Grossman and Krueger (1991, 1995) inquired the relation between environment and GDP growth named as environmental Kuznets curve. Grossman and Krueger (1991) also estimated the impact of North American free trade contract on atmosphere to report the relationship between international trade and environmental degradation. He suggested that when the economic activity gets expansion then it will reduce trade barriers so environment will be affected by this activity. It is meant by the techniques of production changed the increase in economic growth that leads to improvement in the atmosphere. He investigated to access the association among these three affects in Mexico. Cross- sectional data consists of three pollutants of 42 urban countries is taken by him. The results indicated that as the amount of GDP per capita increased then SO_2 emission and smoke also expanded in the atmosphere. The investigation proved the EKC relationship among the economic growth and environmental degradation.

David *et al*. (1998) argued that significant independent variables are neglected from EKC estimation. He used a time-series and cross-section data set of sulfur for an extensive collection of developing and developed countries. In this and they used a new cross-section and time-series data base of SO_2 release for an extensive series of developing and developed countries. The results investigated that data for OECD countries proved existence of EKC but the turning point value was very low as compared to the other EKC proved by data for the whole world. He used Monte Carlo analysis for the explanation of all results regarding the investigation.

Shunsuke and Pradyot (2007) investigated the presence of Environmental Kuznets Curve (EKC) in case of India. For this purpose researcher used state-level industrial Panel data of SO_2 and NO_2 from 1991-2003. The results indicated that as the economic growth rapidly increase in India the environmental degradation decrease. As the pollution abatement approaches were utilized more effectively then SO_2 and NO_2 emission will under control. He analyzed the elements of environmental degradation and found the Environmental Kuznets Curve (EKC) association between the productivity of environment and growth of economy in India. So the combined effect of growth and degradation of environment was negative.

Khalid and Wei (2012) discussed EKC to enquire the relation among carbon dioxide discharge, population density, economic development, energy consumption and trade liberalization in Islamic Republic of Pakistan with annual data from 1971-2008. The analysis of cointegration applying Auto Regressive Distributed Lag (ARDL) bounds examination technique was incorporate. The consequences abide the hypothesis both in long and short-run and inverted U-

shaped relation was establish among carbon dioxide discharge and development. They determined trade confirms the environment positively and population contributed to degradation of environment in Islamic Republic of Pakistan. The economic growth and energy consumption were the main independent variables which bring pollution to environment in Islamic Republic of Pakistan. For this purpose the data of time series was applied.

Ma-Lin *et al*. (2011) explained environmental troubles in China were received worldwide maximizing concentration, EKC was acquired here to authenticate time route of advance for its several areas. The consequences suggested that some regions, such as Tibet, Shanghai, Guizhou, Beijing and Jilin had exceeded their inflection points; Anhui, Liaoning, Fujian, Qinghai and Hainan had no inflection points and it was about 7 years as the others regions take to achieve their inflection points. He suggested that it was necessary to establish few policies to modify or approach the action of achieving point of inflection for each region.

Nawaz *et al*. (2013) discussed the current situation of the environment of Pakistan. For the Purpose of investigation they took the panel data of industrial growth and population growth up to 1980-2008 for Pakistan, Bangladesh, India and Nepal. These four countries are SAARC (South Asian Association for Regional Cooperation) members. To find out the long run relationship Fisher Johansen co integration testing approach applied. The results indicated that industrial and population growth were the major causes to increase environmental degradation in these SAARC countries.

DATA AND MODEL SPECIFICATION

Following variables will be studied in this research by taking data of Time Series from 1972-2008 for Pakistan. Economic Survey of Pakistan, World Bank (WB), Environment Protection Department (EPD) of Pakistan, Emission Database for Global Atmospheric Research (EDGAR) and Data Bank are the sources of data for SO_2, Per Capita real income, Energy Consumption, Population Growth and Trade Openness. The present study is followed by the methodology of Ang (2007, 2008), Shahbaz *et al*. (2010), Khalid and Wei (2012), Nawaz *et al*. (2013), Jalil and Mahmud (2009) and Grossman and Krueger (1995). In this section the hypothetical relation among EKC hypothesis and determinants of per capita GDP, population, trade openness and energy consumption will be focused on. The model of this and is an extension of Khalid and Wei (2012). The following relationship exists among the explained variables and explanatory variables:

$$S_t = f(Y_t, Y_t^2, EN_t, X_t, P_t)$$

The present study follows the model of Khalid and Wei (2012). The relationship is specified as follows:

$$LnS_t = \alpha_0 + \alpha_1 LnY_t + \alpha_2 (LnY_t)^2 + \alpha_3 LnEN_t + \alpha_4 LnX_t + \alpha_5 LnP_t + e_t \quad (1)$$

where,

LnS_t = Natural log of per capita SO_2 emission
LnY_t = Natural log of per capita real income
$LnEN_t$ = Natural log of per capita energy consumption (metric tons)
LnX_t = Natural log of trade openness ratio
LnP_t = Natural log of population growth
e_t = Error term

First of all, properties of time series of the variables of the model, in the time series investigation will be tested. The stationary of the data is essentially evaluated by it, whether the series is stationary or not. Spurious results are usually provided by Non-stationary series and it must be ensure by any investigation is started. Stationary of the data is used to examine by Unit root test, so the Augmented Dickey Fuller test and the Phillips Perron test are used at 10, 5 and 1% levels of significance. This study also applies Autoregressive Distributive Lag (ARDL) for co-integration for empirical research. The ARDL bounds testing method to co integration includes estimating the following Unrestricted Error Correction Model (UECM) following as:

$$\begin{aligned}\Delta \ln S_t &= \alpha_o + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln S_{t-k} + \sum_{k=1}^{n} \alpha_{2k} \Delta \ln Y_{t-k} + \\ &\sum_{k=1}^{n} \alpha_{3k} \Delta (\ln Y_{t-k})^2 + \sum_{k=1}^{n} \alpha_{4k} \Delta \ln EN_{t-k} + \sum_{k=1}^{n} \alpha_{5k} \Delta \ln X_{t-k} + \\ &\sum_{k=1}^{n} \alpha_{6k} \Delta \ln P_{t-k} + \delta_1 \ln S_{t-1} + \delta_2 \ln Y_{t-1} + \\ &\delta_3 \ln (Y_{t-1})^2 + \delta_4 \ln EN_{t-1} + \delta_5 \ln X_{t-1} + \delta_6 \ln P_{t-1} + e_t\end{aligned} \quad (2)$$

The presence of long-run relationship among the variables in the model is estimated. So the null hypothesis of no co integration or no long-run relationship exists between the variables. Ho: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$, H1: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$, The F-statistic is applied to determine the presence of long-run relationship between the variables. The hypothesis of no cointegration is not accepted if calculated F-statistic is more than Upper Critical Bound (UCB). If calculated F-statistic is less than Lower Critical Bound (LCB) then hypothesis of cointegration is accepted. There is no conclusion about co integration if calculated F-statistic is between lower and upper critical bounds. If the results of F-statistic maintain the

confirmation of presence of co integration among the variables, then move to 2nd step of ARDL. In 2nd step the lag orders of variables are chosen using Schwartz-Bayesian Criterion (SBC), Akaike Information Criterion (AIK) and R-Bar Squared Criterion techniques in the ARDL bounds testing method. Error Correction model for S_t:

$$\Delta \ln S_t = \alpha_o + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln S_{t-k} + \sum_{k=1}^{n} \alpha_{2k} \Delta \ln Y_{t-k} + \sum_{k=1}^{n} \alpha_{3k} \Delta (\ln Y_{t-k})^2 + \sum_{k=1}^{n} \alpha_{4k} \Delta \ln EN_{t-k} + \sum_{k=1}^{n} \alpha_{5k} \Delta \ln X_{t-k} + \sum_{k=1}^{n} \alpha_{6k} \Delta \ln P_{t-k} + \theta ECT_{t-1} + e_t \quad (3)$$

In the end we estimate the stability of Coefficients through Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ).

EMPIRICAL RESULTS AND INTERPRETATION

To estimate the property of stationary of time series data, the outcomes of the Augmented Dickey Fuller (ADF) approach are given in the Table 1. The results show that some variables accept the null hypothesis of non-stationarity on level that there exists problem of unit root, but some variable reject the null hypothesis. After taking 1st difference of the variables, the results show null hypothesis is not accepted which means that the variables are non-stationary on level, now these variables are stationary on 1st difference or I(1). Table 2 shows that F-statistic is greater than upper critical bound which is 4.9277 it means that co integration is exists among the variables of Eq. (1). The results indicate that long run relationship present amongst the variables.

As cointegration exist among the variables of the equation 1 used in the study, therefore the results obtain for long run are trustworthy. Table 3 shows the long run estimated results which indicate that energy consumption (EC_t), GDP (Y_t) and population density (P_t) have significant impact on SO_2 emission. But on the other hand GDP square $(Y_t)^2$ and trade openness (X_t) have insignificant effect on SO_2 emission. Positive sign of GDP (Y_t) and energy consumption (EC_t) shows that these variables are positively related with SO_2 emission. But negative sign of population density (P_t) and trade openness (X_t) shows that they are negatively related with SO_2 emission. However GDP (Y_t) have largest impact on SO_2 emission, we can say that increase in GDP will raise the per capita sulphur emission in the atmosphere of Pakistan. Energy consumption (EC_t) also have positive impact on SO_2 emission. The negative sign of GDP square $(Y_t)^2$ shows that there exist inverted U-shaped relationship among the economic growth and environmental degradation. Positive sign of GDP (Y_t) shows that primarily increase in GDP leads to increase SO_2 emission but negative sign of GDP square $(Y_t)^2$ shows that when GDP will double then SO_2 emission will decrease in the atmosphere. So EKC prove by

Table 1: Unit root test results augmented Dickey-Fuller test statistics

Level	Intercept		Trend and intercept	
Variable	t-statistic	p-value	t-statistic	p-value
LnS_t	-0.640484	0.8489	-1.551343	0.7922
LnP_t	-3.509327	0.0152	-2.739197	0.2298
$LnEN_t$	-2.024962	0.2753	-0.181754	0.9911
LnX_t	-2.961970	0.0483	-2.965368	0.1555
LnY_t	-0.377156	0.9024	-1.624450	0.7626
$Ln\ (Y_t)^2$	-0.262246	0.9206	-1.709765	0.7256
1st Difference	Intercept		Trend and intercept	
	t-statistic	p-value	t-statistic	p-value
LnS_t	-5.566433	0.0000	-5.490771	0.0004
LnP_t	-1.007105	0.0000	-2.759180	0.0000
$LnEN_t$	-4.279299	0.0018	-4.734558	0.0029
LnX_t	-6.205664	0.0000	-6.114364	0.0001
LnY_t	-4.715845	0.0006	-4.643550	0.0037
$Ln(Y_t)^2$	-4.628698	0.0007	-4.555405	0.0046

Table 2: ARDL bounds cointegration for S_t (1, 1, 0, 0, 1, 0)
F-statistics = 4.9277

	95 % critical value bounds		90 % critical value bounds	
Equation 1	Lower	Upper	Lower	Upper
	3.0647	4.3919	2.5355	3.7211

Table 3: Estimated long run coefficients using the ARDL approach for S_t ARDL (1, 1, 0, 0, 1, 0) selected based on R-Bar squared criterion

Dependent Variable *ln St*

Variables	Coefficient	S.E	t-ststistics	p-value
$Ln\ EC_t$	13.99900	3.398700	4.1190	0.000***
$Ln\ Y_t$	53.61720	33.40380	1.6051	0.012**
$Ln\ (Y_t)^2$	-2.751400	1.625000	-1.6931	0.102
$Ln\ P_t$	-17.97750	5.282000	-3.4036	0.002**
$Ln\ X_t$	-0.134860	0.685810	-0.19664	0.846
Constant	-314.8268	167.4989	-1.8796	0.071

Diagnostic tests
Serial correlation (χ^2) = 3.7547[0.053]
Functional form (χ^2) = 0.1069[0.992]
Normality (χ^2) = 7.4797[0.824]
Heteroscedasticity (χ^2) = 1.2123[0.271]

Table 4: Error correction representation for the selected ARDL model for S_t ARDL (1, 1, 0, 0, 1, 0) selected based on R-Bar squared criterion

Dependent variable *ln St*

Variables	Coefficient	S.E	t-ststistics	p-value
$Ln\ EC_t$	3.1988000	1.36820	2.33790	0.027**
$Ln\ Y_t$	23.270500	15.4004	1.51100	0.014**
$Ln\ (Y_t)^2$	-1.194100	0.75979	-1.57170	0.127
$Ln\ P_t$	5.9198000	11.3392	0.522060	0.060*
$Ln\ X_t$	-0.058530	0.29849	-0.19609	0.846
ecm (-1)	-0.434010	0.12791	-3.39300	0.002**

*: Indicates that variables are significant at 10% level of significance; **: Indicates that variables are significant at 5% level of significance; ***: Indicates that variables are significant at 1% level of significance

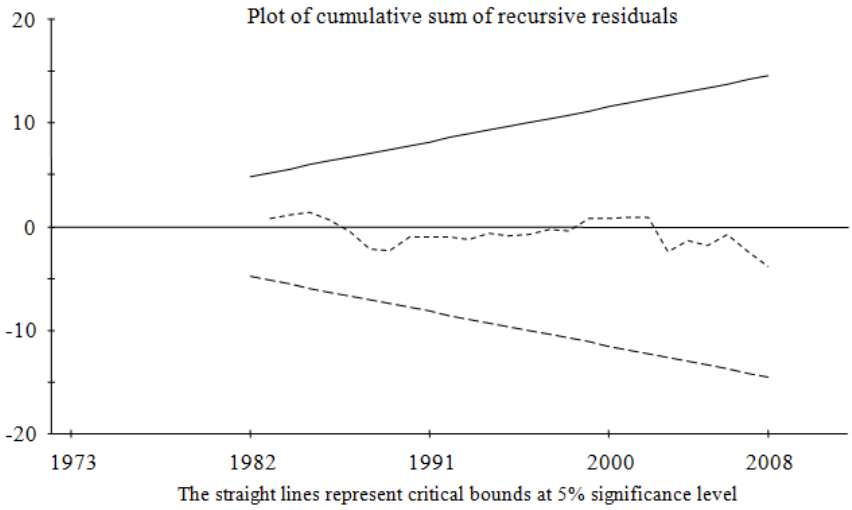

Fig. 1: Plot of cumulative sum of recursive residuals

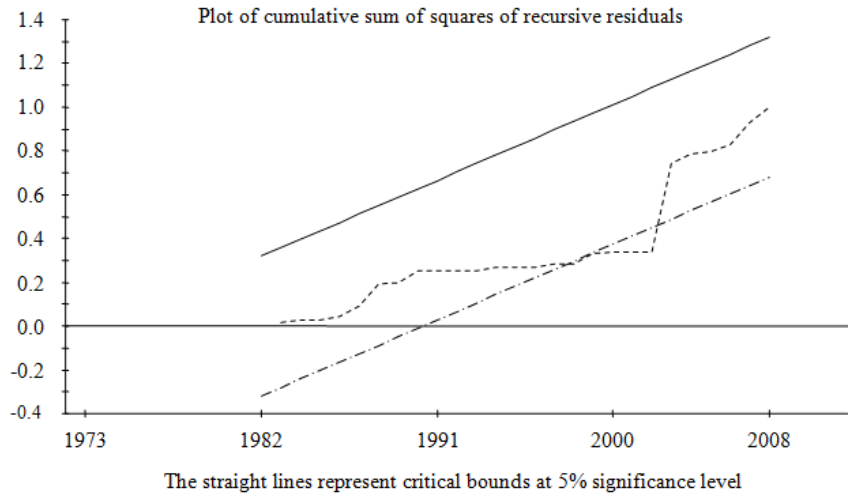

Fig. 2: Plot of cumulative sum of squares recursive residuals

second model of the study. The results of these tests are given in below the Table 3. These results show that the residuals are normally distributed and there is no existence of heteroskedasticity and also no problem of autoregressive conditional heteroskedasticity and serial correlation.

Short run coefficient estimates based on the ECM version of ARDL model are given in Table 4. The results show that error correction term is negative and significant. The value of ecm_{t-1} coefficient is -0.43401 which indicated that after the shocks it will take 27 months to recover or reconstruct the equilibrium. The null hypothesis is not accepted if any of the parallel lines is passed by the plots of both tests. The null hypothesis, meaning all parameters are stable, cannot be rejected when the plots of CUSUM and CUSUMSQ tests do not cross the critical values line of 5% level of significance. This fact points out the structural instability over the phase of investigation (Fig. 1 and 2).

The trends of CUSUM do not cross the parallel lines of the plotted area but the trend of CUSUMSQ cross the parallel lines of plotted area in 1999 to 2003. Hence there is instability among parameters over the period of 1999 and 2003 which indicated that might be economic variables are affected by the event of 9/11.

CONCLUSION

This study investigates the EKC hypothesis and concluded the relationship between carbon emission and other four variables (energy consumption, economic growth, trade openness and population) at the same time by using Auto Regressive Distributed Lag (ARDL) methodology for country Pakistan from the period of 1971to 2008 through time series data analysis. The estimation was based on both short and long-run results and in the end the stability of model is also checked.

There exists long run relationship among the SO_2 and other explanatory variables (Y_t, Y_t^2, EC_t, P_t and X_t). Existence of long run relationship among the explained (SO_2) and explanatory variables (Y_t, Y_t^2, EC_t, P_t and X_t) has taken from the cointegration test. In the long run results GDP (Y_t) and energy consumption (EC_t) are positively related with SO_2 emission. But Trade openness (X_t) and Population density (P_t) are negatively related with SO_2 emission. This means that GDP (Y_t) and energy consumption (EC_t) play their role to increase the amount of SO_2 emission in the atmosphere of Pakistan. Same results are obtained by the short run methodology. In short run results all explanatory variables (Y_t, EC_t and P_t except X_t and Y_t^2) are positively related with Sulphur emission. It means that in Short run population density (P_t) play its role to reduce the SO_2 emission in environment of Pakistan. The results indicate that null hypotheses for the insignificant relation among the explained and explanatory variables are rejected. In case of GDP (Y_t), energy consumption (EC_t), Population density (P_t) we reject the null hypotheses of insignificant relation but we fail to reject the null hypothesis of Trade openness (X_t). The most important and central hypothesis is not rejected by the short run and long run results of ARDL Bounds testing approach that is inverted U-shape relationship exist among the Sulphur emission and economic growth of Pakistan. The results determines that initially the amount of SO_2 emission increase with the expansion of economic growth but when GDP per capita double then it will play significant role to improve the bad condition of environment of Pakistan. The results of CUSUM and CUSUMSQ indicate that there is not stability among parameters over the period of the study.

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