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Dynamic Influences of Urbanization, Economic Expansion and Primary Energy Consumption on Carbon Dioxide Emissions in Pakistan

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ABSTRACT: This study validates a long-run dynamic association between various indicators including, CO_2 emissions, economic expansion, urbanization, as well as primary energy consumption, taking into account a hypothesis of environmental Kuznets curve (EKC) for Pakistan considering the duration between 1980 and 2017. The ARDL bounds testing results show that with each percentage point increase in economic expansion hikes emissions by 3.82%, urbanization increases emissions 0.89%, and primary energy consumption increases 0.54% CO_2 emissions over a long period. Besides, findings confirm the hypothesis of EKC with a reversed U-shape relation for per capita CO_2 emissions and economic progress only in the long run. However, the threshold point of the economy was 1584.46$ year per capita approximately, where economic progress can mitigate the impact of pollution lies beyond the study period. The key policy guidelines derived from this study imply that government should focus economic growth and contain the growing urbanization. It is further recommended that clean energy share in primary energy consumption should be increased using clean technologies to ensure sustainable development.

Keywords: ARDL model, CO_2emissions, EKC, Energy Consumption, GDP, Pakistan, Pollution.

Abbreviations: ADF, augmented dicky fuller; ARDL, auto regressive distributed lag model; CO_2, carbon dioxide; CUSUM, cumulative sum; CUSUMSQ, cumulative sum square; EKC, environmental Kuznets curve; GDP, gross domestic product;

I. INTRODUCTION

Since the industrialization human race is facing the biggest challenge in climate change, scientists have argued that carbon dioxide emissions are the main culprit of this change [1],[2]. Several studies have concluded, that changing climatic conditions are increasing temperatures, and causing ice melt, which are raising the sea levels, and causing extreme weather events that could affect up to half of the coastal population all around the world, and economic loss could be higher than those faced during world wars, statistics also showed concerning point that the average temperature of the earth would increase from 1.5 to 2 times by 2030 [3],[4]. A large part of the emissions is contributed by the energy consumption and generation sector annually [5]. According to the observations of the European Commission, human activity and industrialization have caused an increase in carbon emissions of up to 40% and they are chiefly responsible for up to two-thirds human-made global warming [5].

However, it is necessary to find out factors influencing high emissions, especially carbon dioxide emissions, and to take necessary steps to curb these emissions to protect the environment.

At the start of the economic development, there is less understanding of the potential hazards and, advanced technical knowledge to curb these are not at disposal [6]. Countries that are at the initial stage of development, where poverty is still widespread, corruption is high and have minimal income and revenue sources, with limited funding available for the awareness and conservation of the environment [7]. As a result, economic development damages the environment as pollution hikes with the growth of GDP. The Kuznets curve relationship shows that how per capita income changes emissions effectiveness from positive to negative [8],[9]. In other words, the Kuznets curve states that initially economic growth raises the pressure on environmental pollution, but after achieving a certain level, a rise in growth reduces this pressure of degradation. However, economic prosperity by itself is a solution to mitigate the emissions. Therefore, the application of EKC is still in debate for developed and developing economies because its nature of outcomes is very much sensitive to several factors and time [10].

Kuznets curve hypothesis is applied to see the correlation of per capita growth and environmental degradation. Additionally, to the economic growth, several other factors also influence the emissions of CO_2 such as urbanization, financial growth activities, manufacturing and energy based on fossil fuels [11].

Urbanization is a factor for increasing emissions due to energy consumption. Urbanized areas around the world cause two-thirds of emissions, leading to 70% energy-related emissions [11],[12].

Pakistan is geographically located in the South Asian region, which has a diverse landscape, with various climatic and environmental conditions. Pakistan's economy is considered an emerging economy based on agriculture. In recent years' sovereign nation Pakistan is facing stern challenges like the un-seasonal monsoon, draughts, high precipitation rates, and heat waves, and, all these issues are concerned with global warming due to greenhouse gas emissions.

According to different reports, the average temperature is increasing, and it would increase up to 4-6 degrees Celsius at the end of the century, air quality is worsening, and currently ranks at 153 out of 180 countries, half of the population expected to be urbanized by 2025, and the worst climatic conditions already have caused 14 billion US dollars to the economy, and being a developing country not in a position to tolerate these losses [3],[13].

For energy needs in different sectors, Pakistan relies on indigenous and imported sources of fuels, including oil, gas, LNG, coal, and electricity [14].

Table 1: Selected statistical indicators of Pakistan.

Indicators	2012	2013	2014	2015	2016	2017
GDP (constant 2010$ USD)	188.4	196.7	205.9	215.6	227.6	240.2
GDP per capita (constant 2010$ USD)	1006.073	1028.441	1054.228	1081.294	1117.518	1155.363
GDP growth rate (% of annual)	3.5	4.4	4.68	4.73	5.53	5.55
Population (million people)	187.2815	191.2629	195.3068	199.427	203.6273	207.8967
Urban Population	66.31263	68.11446	69.95695	71.84556	73.78231	75.76171
Primary energy consumption (ktoe)	64142.63	64866.27	66851.25	70378.57	76644.08	80988.71
CO2 emissions (kilotonnes)	170	175	182	189	201	216

Source: [15],[16]

Table 1 depicts chosen statistical indicators examined for present analysis for Pakistan, spanning the years 2012 to 2017. During the period from 1980 to 2017, the Pakistani economy grew at 5.55%, where the country's primary energy consumption increased at the rate of 0.6% in 2017 but increased at the rate of 2.6% from 2006 to 2016 [15]. Similarly, carbon emissions have risen 7.4% in 2017 and increased at the rate of 3.1% from 2006 to 2017 [15]. The population and urbanization growth rate in Pakistan was 2.10% and 2.65% in the year 2017[16]. According to the Asian development bank, the growth rate of the population in Pakistan is more than any other regional country, and half of its population will be shifted to the cities by 2025 [3].

II. MATERIALS AND METHODS

A. Material

Data. This study validates EKC for Pakistan for duration of 38 years, from 1980 to 2017. The data for selected parameters such as Carbon Emissions, GDP, Urbanization, and Primary Energy consumption was taken from British Petroleum [15] statistical review and other above-mentioned variables data were collected from World Bank Indicators (WDI) [16].

Model. To study the association between environmental degradation and economic growth, we used an autoregressive distributed lag (ARDL) based log-linear quadratic time series model to analyze the parameters.

$$\ln \mathrm{C_t} = \mu_0 + \mu_1 lnX_t + \mu_2 (\ln \mathrm{X_t})^2 + \mu_3 lnU_t + \mu_4 lnPEC_t + \epsilon_t \quad (1)$$

C = carbon emissions (metric tons per capita)

X = GDP per capita constant (2010) USD

U = urbanization (ratio of urban population to the total population)

PEC = primary energy consumption (per capita kg of oil equivalent)

In the time series ARDL model equation, the hypothesis of the EKC is acceptable when µ1 > 0 and µ2 < 0. When µ1 > 0, Carbon emissions simultaneously grow with the increase in per capita GDP, and after reaching the peak, emissions start decreasing with an increase in per capita income and become µ2 < 0. The point where environmental retardation occurs is X* = - µ1 / 2 µ2, and exp(X *) represents the monetary value of the position and, the coefficients of the primary energy consumptions, and urbanization, are expected to be > 0, or depending on the economic growth.

B. Methods

Stationary Properties (Unit Root Test). Before running the data in a time series model, it is necessary to validate the data, to see whether the data is stable or not; otherwise, results will not be satisfactory. For checking the unit root properties of data, there are many models at the disposal, such as Dickey-Fuller(DF), Augmented Dickey-Fuller(ADF), Phillips-Perron(PP), Kwiatkowski, Phillips, Schmidt, and Shin(KPSS), and many other. Here we have used ADF and PP unit root tests. The ADF unit root test includes the lag order to give robust results and avoid autocorrelation issues, and the PP unit root test carries the fittings to circumvent the same problem.

In the ADF and PP unit root tests, the null hypothesis rejects to accept alternative hypotheses. For this purpose, the following equations were used.

$$\Delta x_t = \alpha + \beta_t + \Phi x_{t-1} + \sum_{i=1}^{n} \nu_i \Delta x_{t-1} + \varrho_t \quad (2)$$

$$\Delta x_t = \alpha + \beta_t + \Phi x_{t-1} + \varrho_t \quad (3)$$

ARDL (Bounds Testing Approach). Pesaran and Shin developed the ARDL bounds testing approach to study the co-integration relationship of parameters. In this method, there is no restriction on parameters to be integrated of first-order or zero-order or a combination of both. There are many reasons to apt ARDL approach over the other. Such as, it is free from problems associated with the order of integration. The analysis of impacts for independent and dependent parameters of long-run and short-run at the same time. Also, the ARDL method has more suitable properties as well as more consistent results for small samples. Here in this research, short-run and long-run coefficients are examining together. Following Eq. shows the Un-restricted error correction model (UECM).

$$\Delta lnC_t = \alpha_0 + \sum_{i=1}^{j} \alpha_{1i} \Delta lnC_{t-i} + \sum_{i=0}^{k} \alpha_{2i} \Delta lnX_{t-i} + \sum_{i=0}^{l} \alpha_{3i} \Delta \ln (X_{t-i})^2 + \sum_{i=0}^{m} \alpha_{4i} \Delta lnU_{t-i} + \sum_{i=0}^{n} \alpha_{5i} \Delta lnPEC_{t-i} + \delta_0 lnC_{t-1} + \delta_1 lnX_{t-1} + \delta_2 \ln (X_{t-1})^2 + \delta_3 lnU_{t-1} + \delta_4 lnPEC_{t-1} + \epsilon_t \quad (4)$$

In equation, α0 = Constant term; Δ = Difference operator; ϵ_t = White – noise error; α1, 2, 3,4,5 = short–run coefficients; δ0, 1, 2,3,4 = long – run coefficients; j, k, l, m, n = optimal lag length based on Akaike information criteria (AIC) and Schwarz-Bayesian criteria (SBC).

These models allow the separate lag lengths for each of the parameters used in the research.

For case III (Unrestricted intercept and no trend) model, the null hypothesis (H0: α0 = δ0 = δ1 = δ2 = δ3 = δ4) considering no co-integration among the parameters examined against the alternative hypothesis (H_alternative: α0 ≠ δ0 ≠ δ1 ≠ δ2 ≠ δ3 ≠ δ4) respectively. By the case (III), the F- statistics value achieves, compared with the tabulated critical value given by Pesaran and Shin confirmed the co-integration among the parameters. There are two critical values tables one is by Pesaran and Shin and the other one by Narayan. The table achieved by Pesaran *et al.,* (2001) are considering for samples ranging from 500 to 1000 observations, but on the other hand, the table created by Narayan is suitable for sample ranging 30 to 80.

In comparison with other traditional co-integration tests, the ARDL framework complies better with smaller sizes of sample and produces improved results. There are three conditions regarding the co-integration test. The conducted F- stat value is greater than the tabulated critical value, then one may say that it is co-integration among the variables. The second F-stats calculated value is lower than the tabulated critical value, and then there is no co-integration among the parameters. And the third is that when the value falls between the upper and lower bounds, then the co-integrating results are not conclusive. These all F-stats results are compared with the help of null and alternative hypotheses.

As the co-integration establishment was confirmed among parameters with the bounds test and long-term parameters coefficients achieved, short-term parameters coefficients establishment was confirmed by error correction model (ECM) based on the ARDL framework.

$$\Delta lnC_t = ƛ_0 + \sum_{i=1}^{a} ƛ_{1i} \Delta lnC_{t-i} + \sum_{i=0}^{b} ƛ_{2i} \Delta lnX_{t-i} + \sum_{i=0}^{c} ƛ_{3i} \Delta \ln (X_{t-i})^2 + \sum_{i=0}^{d} ƛ_{4i} \Delta lnU_{t-i} + \sum_{i=0}^{e} ƛ_{5i} \Delta lnPEC_{t-i} + \gamma ECT_{t-1} + \epsilon_t \quad (5)$$

ƛ0 = Constant term

Δ = Difference operator

ϵ_t = White – noise error

ƛ1, 2, 3,4,5 = Short-run coefficients

γ = Long–run coefficients with error correction term (ECT)

a, b, c, d, e= optimal lag length based on Schwarz Bayesian criterion (SBC)

The ECT represents that how much time is needed for short-run parameters to compensate for the long-run parameters. For ECT based model, the time term should be negative and statistically significant. Finally, to ensure stability for the ARDL framework, diagnostic tests such as Serial Correlation, Ramsey Reset, Normality, Heteroscedasticity, Cumulative Sum(CUSUM), and Cumulative Sum of Squares (CUSUMSQ).

III. RESULTS AND DISCUSSION

This research examines the multivariate relationship of economic progress and environmental degradation with the selected parameters; initially, at the first step, the unit root properties of selected parameters were checked using PP and ADF unit root tests. The maximum slack is calculated by the formula (K_{max} = int{12*(T/100) ^0.25}) given by Schwert [5]. Meanwhile, PP and ADF unit root tests, the slack length chose with SBC based standards. Table 2 represents the unit root test results. All the parameters are stable at I(1) or first difference whereas, urbanization is stable at I(0) or level, but none of the parameters are stable at I(2). Therefore, ARDL bounds testing implied to check an establishment of long-run association among chosen parameters.

Table 2: PP and ADF unit root tests.

Variables	I(0) t-statistics	I(1) t-statistics	I(0) t-statistics	I(1) t-statistics
X	-1.218	-3.908***	-0.551	-3.908***
X2	-0.986	-3.850***	-0.382	-3.850***
U	-9.165***	-3.274**	-1.964	-0.651
LNPEC	-2.042	-4.476***	-2.214	-4.438***
LNCO2	-1.976	-7.125***	-1.976	-7.23***

Notes: a: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant
b: Lag Length based on SBC

The co-integration relationship among the parameters was examined using the ARDL bounds testing method. The optimal slack lengths for the bounds testing were obtained by employing the Akike Information Criteria (AIC) and Schwarz Bayesian Criteria (SBC). The SBC aids in determining the possible minimum slack length, and AIC aids in determining the available highest slack length for the ARDL bounds testing method. Table 3 shows present study was conducted with the ARDL (1,0,1,1,1) model which is minimizing SBC information criteria.

Table 3: Model selection summary.

ARDL	AIC	BIC*	HQ
(1, 0, 1, 1, 1)	-5.305403	-4.91755*	-5.16741
(1, 1, 0, 1, 1)	-5.304131	-4.91628	-5.16614
(2, 0, 2, 0, 1)	-5.335435	-4.90449	-5.18211

Table 4 represents the confirmation of the co-integration relationship for Case-I and Case-II by rejecting the null hypothesis and accepting the alternative hypothesis. The generated result of F-statistic values with the 1% show significant level generated through ARDL model and are in line to values of Pesaran and Shin [17], and Narayan's [18] for four parameters, co-integration among the parameters at a 1% significant level was achieved.

Table 4: Bound Test results of the model for the long run.

k = 4	CASE -II		CASE -III	
F-statistic	14.79755***		17.32865***	
Pesaran et.al Critical Table Value	I(0)	I(1)	I(0)	I(1)
10%	2.427	3.395	2.66	3.83
5%	2.893	4	3.202	4.544
1%	3.967	5.455	4.428	6.25
Narayan Critical Table value	I(0)	I(1)	I(0)	I(1)
10%	2.099	3.181	2.47	3.39
5%	2.457	3.65	2.89	4.00
1%	3.282	4.73	3.96	5.45

Note: Asterisk (***) sign represents the significance level at 1%

In Table 5, all the long-term coefficients show significance and validating relationship with CO_2 emissions (ln C). GDP(X), urbanization (U), and primary energy consumption (LnPEC) having a positive relationship with emissions showing that they cause a hike in CO_2 emissions in long-term. The coefficients of GDP and its square were found to be 3.826293 and -0.25966, shows that $\mu1 > 0$ and $\mu2 < 0$. The result affirms an establishment of the EKC for a long term for Pakistan. The critical point of the monetary value was found to be (1584.462) $, which is way more than the sample values of per capita GDP. ARDL model also checked for the proper functioning and functional form with different diagnostic tests shown in Table 6.

Table 5: Coefficients of long run variables on the basis of ARDL model.

Variables	Coefficient	t-Statistic
X	3.826293***	4.097309
X2	-0.25966***	-3.815
U	0.893523***	5.375637
LNPEC	0.541592***	10.03096
C	-29.90694***	-9.9352

Notes: The asterisks ***, ** and * denote significant at 1%, 5% and 10% level

Table 6: Diagnostics represent the relationship of the model.

Diagnostics	F-statistic	P-value
BG-LM(Serial correlation)	3.012966	0.0936
Jarque- Bera	2.0257	0.36318
BPG	0.751461	0.6467
ARCH	0.199773	0.6577
Ramsey Reset	0.058884	0.81

For the autocorrelation issue, the Breusch-Godfrey test (BG-LM) was employed in the model, and it confirmed there was not any auto-correlation issue within the model. Breusch-Pagan-Godfrey (BPG) and ARCH tests confirmed that there was no issue of Heteroscedasticity to the model. The Jarque-Bera and Ramsey- Reset tests also highlighted error term was distributed normally, and model had proper functional form.

Table 7, representing short-term coefficients and coefficients of the ECM based on ARDL model.

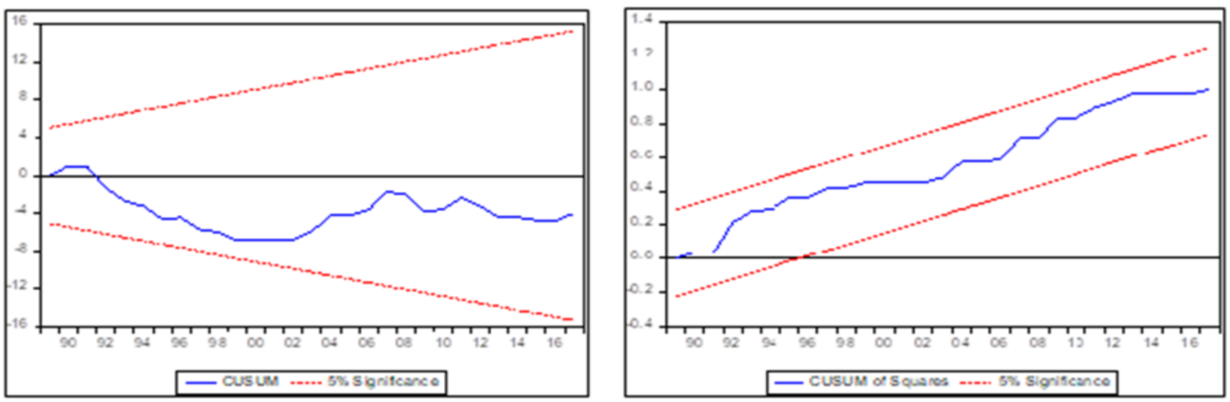
Table 7: Coefficients of short run variables on the basis of ARDL model.

Variables	Coefficients	t-statistics
D(X2)	-0.41274***	-8.81086
D(U)	8.722503***	5.152652
D(LNPEC)	0.313591***	3.251923
ECT	-1.45861***	-9.92945

ECT = LNCO2 - (3.8263*X -0.2597*X2 + 0.8935*U + 0.5416*LNPEC)
Notes: The asterisks ***, ** and * denote significant at 1%, 5% and 10% level

Urbanization and primary energy consumption coefficients are influencing and significant. While coefficient of **ECT** is negatively significant at one percentage level with a value of -1.45861, showing that inequalities will be removed within two years. The parameters stability checked using cumulative sum (CUSUM) of recursive residuals and the cumulative sum of square (CUSUMSQ) tests. The CUSUM test represents fundamental variations for regression coefficients, whereas CUSUMSQ test finds abrupt or sharp changes in regression coefficients.

Fig 1 (a) and (b) of CUSUM and CUSUMSQ tests of the model stability conforming that model is stable as the CUSUM and CUSUMSQ line is falling within the limits of 5% of critical bounds.



(a) **(b)**

Fig.1. CUSUM test **(b)** CUSUMSQ test.

IV. CONCLUSION

Present study analyzed the establishment of the EKC hypothesis for Pakistan considering the duration starting 1980 to 2017, by applying the ARDL bounds testing method. Considering the stationary level of parameters, we chose to use the ARDL method as urbanization was I(0) level stationery and, all the other selected parameters were first order I(1) stationary. We modeled the influences of per capita GDP and its square with other salient parameters including urbanization, and primary energy consumption.

The results of the selected parameters for the long run with GDP and its square showing that with each percentage point increase in urbanization and primary energy consumption emissions hikes by 0.893523% and 0.541592% respectively.

In the short run, there was no establishment of the EKC hypothesis with regards to the scenario of Pakistan within the selected duration and 1% increase in urbanization hikes emissions 8.722503%, on the other hand with each percentage point surge in primary energy consumption hikes emissions by 0.313591% respectively. Therefore, short-term policy changes will not best fit for balance of environmental and economic growth for a country like Pakistan.

Observed results underlined a validation of the EKC hypothesis for a long period, but not for a short period. These outcomes are in line with the other similar studies, Pata [5],[11], who analytically confirmed EKC for Turkey and Nutnaree Maneejuk *et al* [19] for 44 different countries.

Moreover, thresh hold point for per capita income in the long run calculated was (1584.462)US dollars, which was outside of the total period, these results are parallel finding to Pata [5],[11],[20] for turkey and Zhang *et al.* [21] for 121 different countries and found 108 countries did not reach for the turning point.

V. FUTURE SCOPE

As far as recommendations are concerned that Pakistan's economic growth is fluctuating, population and urbanization are increasing and, primary energy consumption with carbon emissions are also increasing throughout the study period, therefore:

(1) Pakistan should focus on its economic growth as its economy is weak.

(2) It should focus on plan urbanized area growth as its urban population is expected to be half of its total population by 2025.

(3) It should increase clean energy share to its total primary energy consumption to grow sustainably with pollution control.

Conflict of Interest: The authors state that they have no known competing financial interests or personal connections that might have influenced the research presented in this publication.

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