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Signifying the Imperative nexus among Co2 Emissions, ICT's and Economic Growth: A case study of Pakistan

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ABSTRACT

Pakistan is facing the problem of environmental pollution. Environmental Pollution is caused by the use of coal energy consumptions, infrastructure proxy as transport, for economic growth but the concerns of environmental pollution cannot be ignored. The purpose of this study to investigate the impact of information and communication technology, gross domestic product, (GDP) with CO2 emission in Pakistan for a long-run by using annual time series data from 1990 to 2020. Using Augmented Dickey-Fuller Unit Root and Phillips Perron Test for stationary, Autocorrelation and ARDL Bound technique. The estimated results of ARDL indicate that economic growth (GDP), increase the CO2 emission in Pakistan both in short run and long run. While Information and communication technology decrease the CO2 emission Based on the estimated results it is recommended that policy maker in Pakistan should install advance technology and convert traditional energy sources such as coal energy consumption to solar energy that can reduce the CO2 emission and also ensure sustainable economic development of Pakistan.

Introduction

Various researcher's recommendations clue us to the given below introduction background

The fundamental cause of global warming and environmental change is carbon dioxide emissions. Carbon dioxide emission has expanded rapidly since the start of the 20th century. In 2016, China revealed 7.175 CO2 emanations (metric tons per capita). In 2007, China was viewed as the world's biggest carbon dioxide emitter and attempted to decrease CO2 emission in 2020 (Wang et al., 2014) .Worldwide CO2 emanations in 2014 surpassed 35.9 billion tons, instead of 1.6 times in 1990. Normal worldwide temperature has been risen fundamentally in ongoing many years (Yao et al.,2019). lso, Information and communication technology (ICT) can work on ecological quality by presenting various methodologies like disappear and disbandment. Consequently, an unexpected analysis might recommend that ICT further develops proficiency in energy. Accordingly adds to the decrease in emission of CO2 (Haseeb et al., 2019).

Pakistan is a non-industrial country in Asia, its economy is developing quickly and financial development relied upon to proceed in a similar pattern. Pakistan's economy relies upon agriculture, which is the country's predominant area; however,

the farming region is contracting due to the rapid development of Pakistan's modern area. What's more, fast population development prompts deforestation. Pakistan is one of the top positioned in Asian countries dealing with the issue of deforestation. Financial development in the modern area burns-through energy for development that prompts ecological obliteration. Pakistan has high energy interest and conventional source of energy is utilized to see its fast expanding energy demand (Wolde et al., 2010). Ahmed et al. (2015) environmental squalor affects the atmosphere and health of the human being in Pakistan. Yang et al. (2017) specified that environmental degradation is affected by huge amount of greenhouse gas emission, including carbon dioxides emission etc. The investigation of proposed that transportation area is the main source of carbon dioxide emission (Du et al., 2019).In the course of the past thirty years, the broad reception of ICT has further developed usefulness and productivity of energy in the majority of the economy. The concentrate fundamentally reports these possible advantages of ICT all over the world. In any case, small consideration has been rewarded to the environmental effect of ICT. Consequently, the relation among information and communication technology (ICT) and environmental manageability isn't yet clear (Khan, 2019). Khan et al. (2020) to explore the Outcome of ICT with environmental supportability. The also discussed significancey of ICT is especially reasonable for the current period of modern upset and development in technology. Similarly, the environmental maintainability is a worldwide problem and a significant role of ICT in this eco-friendly sustainability. Sassi et al. (2013) According to Sassi and Goaied the headway in ICT have prompted numerous primary vagaries, for example, rearranging of economic, extension in trade leading to the capital streams and also improved availability of information. Advancement in each economic sector is dramatically affected through ICT, particularly through liberalization process and indeed, even the development financial analysts' gauge that monetary development is driven by interests in ICT. Khan et al. (2019) Pakistan's weakness to environmental change is positioned most important in the whole. The energy and transportation parts are the source of pollution and they altogether create half of the pollution. Energy utilization prompted CO2 emission in Pakistan increase from 68,242 (kt) in the year of 1991 to 166,298 (kt) in 2014. After the improvement in industrialization, transport sector insistently affects fossil fuel byproducts across the world.

Due to the mention variables GDP, CEC, and Infrastructure in the past three decades' carbon dioxide emission was increase. We give the above refrencive evidence of ICT because up to great extent it can reduces environmental pollution majority.

Problem Statement

Environment is one of the most significant factors for humans and any others remaining living things. With the fast improvement in the industrial sector, it is important to take measures against the expansion in energy utilization and strain on natural resources and environmental pollution issues that happen because of this cycle (Ozturk et al., 2020)

It is accepted that the implementation of ICT will be minimize CO2 emission by creating proficient transport structures, building more smartness in cities, and leading manufacturing processes (Akande et al., 2019). The existing ICT literature for the most part centers on created nations and generally ignoring less developed countries in Asia (Salahuddin et al., 2016. Akande et al., 2019).

According to various studies exploration has been led for short run and for a small number of countries because of information inaccessibility for ICT indicators, be that as it may, it very well may be stretched out to all countries. In addition, the review has utilized just CO2 as proxy for environmental degradation for ecological corruption yet different signs of degradation in environmental may also be more for further investigation However, ICT framework has prompted huge consumption of electricity which is the dynamic causes of worldwide emission of CO2. It had been assessed that ICT area has affected higher consumption of electricity universally from 2.59% in the year 2007 increase 3.56% in the year 2012 (Salahuddin et al., 2016). Furthermore, Energy consumption in the infrastructure (transport) sector has a hostile impact on environmental enactment (Hafeez et al., 2020 and Yang et al., 2020). Further such review will add to the arising writing on environmental and as well as ICT feasible issue by leading a near investigation the effect of ICT with CO2 emission for a huge number of advanced as well as less advanced countries (Khan at al., 2020).

The fundamental target of our study is to test the impact with (ICT), utilization of energy consumption, GDP, emission of CO2 in Pakistan economy. In Various research studies concluded that environmental degradation is the cause due to using consumption of energy as well as economic growth in advance countries (khan et al 2020). In our research study we will explore the Impact of ICT, GDP, consumption of energy and as well as infrastructure with emission of CO2 in long run to the Pakistan economy.

Significance of the Study

Increasing of CO2 emission in Pakistan has been regularly faced with problems due to rise in GDP,. The Lack in previous studies the impact of ICT on CO2 emission has critical idea. Our research study is considered significant to understanding the impact of the ICT with CO2 emission in Pakistan economy for the years between 1990 and 2020.

Environmental quality ascents with expanding ICT in nations with high and center degree of CO2 emission. Nonetheless, this outcome doesn't hold for nations with low per capita CO2 emission. Consequently, we will suggest that for the most part nations with low per capita discharges particularly Pakistan take part in the ICT cycle more. Right now, we ought to additional feature one issue. Moves toward be taken by these districts towards globalization may be restricted somewhat because of their lower monetary circumstances and the chance of losing near advantage in exchange. For that reason, to help these nations, innovation obstructions ought to be eliminated. In addition, as the rising utilization of obsolete innovation could additionally hurt the climate, the states ought to empower the reception of natural related advances by lessening the monetary expenses and advancing green arrangements (Avom et al., 2020; Liu et al., 2020)

Carbon emission guarantee break out to be a gamble towards the authenticity of the biosphere climate. Remembering the headway for the showing of engines and different hardware, the arrangement of oil based ware and further flammable gas shut in the shocking improvement of oil subordinate outcome dependent upon environmental parts (Patterson et al., 2019). The role played through ICT within the improvement of clever and sustainable capitals internationally cannot be over-emphasized (Nizam et al., 2020).

Literature Review

Environmental economists are concerned about declining activity as rapid economic development and international trade link different economies with better living standards. In line with the recent focus on climate change and environmental change, developed countries are either emitting CO2 from low carbon activity (production-related emission) or shifting to more environmentally friendly production (renewable energy). Increase we are working on quantity limits). Developed countries import most of their carbon-intensive products from less environmentally regulated countries (developing countries) to meet growing demand and, as a result, reduce production-related emission. Doing However, CO2 emission due to consumption will increase. Recently, many studies have investigated various determinants of environmental change related to carbon dioxide emission. For some instances Mirza et al. (2019) discovered the effect among ICT, CO2 emission, and CEC of 81 non-industrial countries in the period of 2010 and 2014. Method Two-step system has been used to analyze the relation among the notice factors. The findings in this exploration concentrate on help the hypothesis that ICT can be utilized as strategy implement to minimize the negative significance of ecological exploitation on comprehensive turn of events. The outcomes propose that ICT in relationship per capita positively affect with CO2 emission comprehensive advancement in an unequivocal deterioration. Raheem et al. (2019) explored the capability of the economic growth, ICT as well as CO2 for G7 countries in the period of 1990 to 2014. In this review PMG technique was used, the finding is that over the long run there is positive correlation between ICT and CO2 emission, while Financial Development is a powerless determinant. In any case, their association indications that their mix impact proceeding economic growth, such that positive impact in short and negative impact for the long run. Algarini. (2019) studied the causal relation among economic growth (GDP), CO2 emission, consumption of energy got from gas and oil in the time of 1990 to 2017. In this analysis autoregressive models have been utilized and Granger causality Wald tests, they advocate that there is conjoint connection among Economic growth (GDP) and also consumption of energy, economic growth and Carbon dioxide emission from gas and Carbon dioxide emission. Thus, there is a one-way causality goes from CEC, CO2 emission and from oil and energy creation to increase CO2 emission. The result confirmed that utilization of energy is basic show as a supplement to the significant elements of work; both land as well as capital in Saudi Arabia. Khan et al. (2019) concentrated on Pakistan's decoupling status between environmental effect and economic growth (GDP) and to break down main thrusts of carbon emission over a stretch of time of 1990-2014. Log Mean Divisa Index (LMDI) procedure was utilized. The result proposes that Pakistan has encountered four decoupling situations with; the most unmistakable is the costly negative decoupling status. Besides, energy power and carbon force typically empowered decoupling, while economic growth (GDP) and energy structure limited it. The population impartially affects decoupling. Qaiser et al. (2019) Determined on the correlation among CO2 emission, coal energy consumption, as well as economic growth (GDP) for (ASEAN 5) countries for the years of 1980 to 2016. EKC and Granger procedure are used. In Previous investigations the finding is that have analyzed the Effect of GDP, CEC and CO2 for the countries of ASEAN 5 which is one-sided in light of the fact that they neglect to represent cross-sectional reliance (CD). This study explore that traditional tests are applied for the dataset propose a deceptive decision interpreting to the EKC and Granger causality test the correlation among CO2, consumption of Energy, GDP in the existence of CD. Rasool et al. (2019) In This exploration study was utilized an (ARDL) to examine the impact of oil costs, energy power of street transport, economic development (GDP), and populace thickness on carbon dioxide (CO2) emission of Pakistan's transport sector during the 1971-2014 period. The ARDL test examines the cointegration and long-run connections among the factors and the headings of causal connections are found through the Granger causality vector blunder revision model (VECM). The long-run results determine that expansions in oil costs and financial development help to lessen the vehicle area's CO2 emission. The after effect of this study can help experts in Pakistan to foster appropriate energy arrangements for the transport sector. Jafri et al. (2020) this study was examined the symmetric and uneven effects of genuine foundation on energy use, economic development, and air contamination of

Pakistan over the time of 1990-2019. The ARDL results for the energy use model suggest that airplane conveying warships (ACC) and street framework support energy use in the brief period. For the advancement model, the impact of exchange is negative and basic in both short run and long run. The results for environmental pollution model suggests that (ICT) is firmly associated with CO2 emission. The street has a positive effect CO2 emission while ACC has a negative for a really long time. The nonlinear ARDL results reveal that negative piece of ICT unfavorably influences energy usage, while positive part makes unimportant difference. At last, the positive shock to street determinedly effect pollution anyway the negative shock makes no change. Ali et al. (2020) studied effect of consumption of non-renewable energy, economic growth (GDP), with CO2 in Pakistan for years of 1971 and 2014. In this study they have applied board ARDL model to investigate the since quite a while ago run elements and VEC model determined Granger causality technique to show the causality course. Three bivariate conditions technique has been used, the exact result in this research study is set up key affiliations that must significant arrangement suggestions. The consequences of auto-backward circulated slacks (ARDL) affirmed the EKC theory that relation among CO2 emission and economic growth (GDP) is become U-shape emphatically affect CO2 emission over the long run. Besides, CO2 negative affects economic development of events whiles the effects of petroleum derivative. Khan et al. (2020) investigated the correlation of ICT with CO2 emission for 91 panel's countries in the period of 1990 to 2017. This research study showed that ICT file through top part examination and the presence of cross-sectional reliance in the mention data. OLS method was utilized for the impact, and framework summed up strategy for second's assessment methods with board remedied standard mistakes (PCSE) to obstruct the problems of cross-sectional reliance in the mention Data. The result of this research also shows that ICT minimize CO2 emission on behalf of the complete example of countries. Besides, presence of the EKC is affirmed for the complete example just as for created and non-industrial countries. Khan et al. (2020) studied the correlation among consumption of energy, GDP, CO2 emission for Pakistan economy and using time series data for the years of 1965 and 2015. ARDL method was used and result showed that consumption of energy and economic growth increment CO2 emission for Pakistan economy both short and in long run. In the view of assessed results showed that the arrangement producer in Pakistan ought to take on and advance such environmentally friendly power sources that will assist with satisfying the expanded need in energy by supplanting old customary sources of energy like oil, gas and coal. Osobajo et al. (2020) explained correlation of economic growth, consumption of energy, with CO2 emission. The correlation of economic growth, consumption of energy with CO2 emission was surveyed utilizing relapse examination by the OLS relapse and fixed impacts methods, Granger causality technique and panel cointegration tests was used. Data has been taken from 70 countries for the period of 1994 and 2013 to analyze. After the effect of the Granger causality tests uncovered that the variables have a multiple causal correlation with CO2 emission, while consumption of energy has a one-way correlation.

Shehzad et al. (2020) the globe has confronted innovative luxuriousness that hugely upset the existences of mankind. Today, the assembling interaction of the energy area, creation area, farming area, and administration area is solely or to some extent in view of ICT instruments. The critical expectation of this examination is to figure out the effects of the use of ICT on CO2 emanation. Be that as it may, this examination additionally assesses the impact of interest in ICT and the exchange of ICT devices on CO2 emanation. Further, the assessment analyzed the means of climate Kuznets bend (EKC) hypothesis, for the country of Pakistan. The examination utilized an autoregressive dispersed slack (ARDL) model and found that the use of ICT adversely affects CO2 emanation. Also, the long-run results uncovered that the import of ICT gear is more advantageous for the climate quality of Pakistan. Be that as it may, ICT contraption fabricated in Pakistan could deliver electronic waste due to non-use of green innovation.

Mendonca et al. (2020) this study was to check the effect of Gross Domestic Product (GDP), populace development and the age of sustainable power sources on CO2 emission in the 50 biggest world economies over the course of the years 1990 to 2015. To do as such, a progressive relapse displaying was performed, taking into account "country" as the most far reaching level and "year" as the most unambiguous one. The outcomes affirmed the positive effect of GDP and populace on CO2 emission and sustainable power age as a method for lessening emission. China and Denmark hung out in the examination. The previous has turned into the biggest producer of CO2 on earth, while the last option has expanded its portion of sustainable power in its electrical framework by in excess of multiple times and showed a propensity to diminish CO2 emission.

Myszczyszyn et al. (2021) the main purpose of this research study was to conclude the long-run and short-run relationship between CO2 emission, energy consumption, and the level of economic growth of (GDP) in the V4 nations. These nations, being EU individuals since 2004.The aftereffects of the exploration are differed, yet the creators affirmed, particularly on account of Poland, the drawn out relationships between's the concentrated on factors. Temporarily, such interdependencies likewise happened, particularly between the degree of energy consumption and the degree of CO2 emanations.

Sharif et al. (2021) Studied the role of carbon emission (total and disaggregate structures) alongside road infrastructure on GDP for the years of 1972 and 2017. The technique was fully modified ordinary least square (FMOLS) and dynamic standard

least square (DOLS) approaches. Result state that there is a positive noticeable correlation between roads infrastructure and economic development. Though, the effect of fossil fuel byproducts (independent of total or disaggregate forms) is negative on economic development. The findings propose that the enhancements in economic development can be accomplished through road infrastructure structure advancement yet at cost of decay of environmental excellence (expansion in carbon emission).

Aslam et al. (2021) studied correlation of economic growth (GDP), with CO2 emission for Chinese spending Chinese budget alongside with trade plainness. It likewise appraises the EKC curve. the added up to appraisals unveiled that profession upsurge the Chinese CO2 radiating. Despite the fact that GDP per capita demolishes CO2 emission for the prolonged stretch of time. it likewise starts exchange receptiveness erection, relating change breakdown powers the disease about the thought from the delay of CO2 discharge and GDP, correspondingly which is significant forecasters of Chinese CO2 emission.

Chien et al. (2021) studied the impacts of the logical factors change across various quantiles of CO2 emission. Methods of Moments Quantile Regression MQR has been used. The result showed that economic growth and CO2 emission through totally quantiles, while ICT significantly moderate the degree of carbon dioxide outflows just at lower emanations quantiles just at lower discharges quantiles. Additionally, the outcome affirms the presence of the EKC hypothesis. Financial development and data and correspondence innovations on carbon dioxide outflows. The specific discoveries of DH board heterogeneous causality test confirmed bidirectional causality among the model limits.

Alatas. (2021) investigated relationship between CO2 emission and ICT for a huge example of countries. 93 countries are taken for sample size and taking for the period of 1995 to 2016 and three variables are used as an alternative for ICT i.e., people using the internet; fix phone memberships, and mobile cell memberships. From the strategic perspective, they initially arrange nations utilizing endogenous information driven calculation dependent on the temporary conduct emission of CO2 and also obtained low, middle, high level of CO2 emission in country. The result confirms the animation of cointegration between the variables. Moreover, ICT particularly affects CO2 emission.

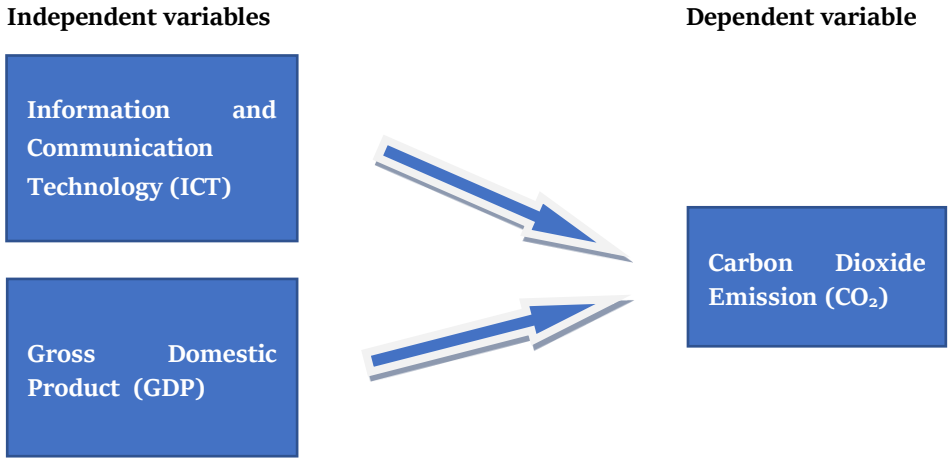
Xion et al. (2021) discussed the expected to reduce the gap for the research study by considering at the impact of energy expenditure, environmental pollution with economic development by finding the casual relationship among variables for the time period of 1995 to 2015 in light of the fact that it has been seen that with improvement of economy, ecological problems reliably increment. Effects of both traditional and momentum energies were inspected in this exploration a few informative factors will be utilized: Renewable energy consumption, CO2 outflow, GDP. Environmental pollution will be taken as the intervening variable that the impacts of this correlation between energy consumption and economic development. ARDL model was applied in this research study.

Shabani et al. (2021) explore the correlation among CO2 emission, GDP, consumption of energy, as well as urbanization in the Economic Cooperation Organization member countries for the period of 1990 to 2014. For this relationship between mention variables completely MOLS, Dumitrescu–Hurlin causality, two-stage Engels-Granger methods was used. The Results of the EKC for the Economic Cooperation Organization in short and long run was confirmed the validity. As per the Dumitrescu–Hurlin causality strategy, there is a causal two-way impact among CO2 emission, GDP, and urbanization.

Conceptual Framework

Conceptual framework used in this study can be explained as in figure below:

Figure 1: Proposed Model



Operationalization of Variables

Carbon dioxide Emission (CO2)

Carbon dioxide as "without color, scentless gas delivered by the consuming of natural mixtures and petroleum derivatives, by the cycles of breath also deterioration, and by volcanic movement, and consumed by plants during photosynthesis." The passage clarifies how "carbon dioxide is normally present in air (around 0.03 percent)

Information and Communication Technology (ICT)

ICT discusses to the PC and internet connections used to deal with and convey data for the purpose of knowledge. Electronic learning using data network-like the web, an intranet (LAN) or then again extranet (WAN) regardless of whether entirely or to some degree, for course conveyance, association or potentially assistance. Electronic learning is a subset of e learning and alludes to picking up utilizing a web program like the model, or internet explorer.

Gross Domestic Product (GDP)

Gross domestic product (GDP) : It shows overall performance of economic level of any country, which is earn from the internal sources of the country in the period one year to the next year.

Research Methodology

In this part includes the research methodology of the study. We will outline the nature of the research data, sample design, source of data collection, and the selection of population and sample of the study, the type of data, and tools for data analysis. The data that has been set for the study is a time series and covering the years of 1990 to 2020.Three variables CO2 emission, ICT, GDP, will be measure in terms of Pakistani local currency have been selected for the study and the data will collect from the World Development Indicators (WDI). We will use the Secondary data to pursue the study.

In our research study for data collection, we will be using main source of internet. A time series data from 1990 to 2020 will be use to analyze the dependency of carbon dioxide Emission (CO2) on ICT, Gross domestic product (GDP), for a long run in Pakistan. And the data will take from the website World Development Indicators (WDI), World Bank.

In our study we will investigate the impact of ICT, Gross Domestic Product, on CO2 emission of Pakistan economy. Therefore, the research uses the correlational type of analysis based on secondary data. Pakistan's economy data of carbon dioxide emission (CO2), Information and communication technology (ICT), Gross domestic product (GPD), will be analyze. ICT, GDP, will be taken as independent variables while its effect will be examined on CO2 emission of Pakistan economy. Secondary data will be collected from World Development Indicators (WDI) website source for the years of 1990 to 2020.

Model Specification

The study will use multiple regression model. The multiple regression model is adopted with five variables CO2, ICT, GDP, Furthermore, in order to capture a clear impact of each independent variable on the dependent variable carbon dioxide emission.

General model

$$CO2i, t = f (ICT i,t, GDPi,t)$$

and we can write.

$$CO2 = \beta o + \beta 1ICT + \beta 2GDP + U$$

Where

Carbon emission (CO2): dependent Variable

ICT, GDP : independent Variables and U: error term.

In the above model CO2 denote a carbon dioxide emission is dependent variable followed by ICT, GDP, as independent variables. The subscripts i and t depicts time (1990-2020) and Time series dimensions of Pakistan economy.

Table 1: Measurement of Variables

Variables Source	Definition
CO2 (Dependent)	Carbon dioxide emission (Metric tons per capita)
ICT (Independent)	Information & communication Technology
WDI	World Development indicators
GDP (Independent)	Gross Domestic Product

Tests

To investigate the Impact of nominated variables, in the first step we will conclude whether time series data have stationary or not. Therefore, we will use Augmented Dickey-Fuller (ADF) test and Phillips Perron test to check whether our data has stationary or not. After the use of ADF Unit root test for stationary or non-stationary we will check the autocorrelation/ serial correlation problems among the variables. Now to check whether variance of the errors term from a regression model is dependent from the values of the autonomous variables. For this purpose, we will use Heteroscedasticity test. After heteroscedasticity test, we will use Stability Test. To checking the reliability, we will use diagnostic tests. In diagnostic tests includes serial correlation, normality and Heteroscedasticity. We will check the probability value with 5% significance level.Ramsey Regression Equation Specification Error Test (RESET) test is a common description test for the linear regression model. Further specifically, it tests whether non-linear combinations of the fitted values help describe the answer of variables (Ramsey, 1969). Technically Y= E(y/x) = β, the Ramsey test then tests whether (βx)2, (βx)3, (βx)4,……. (βx)k has any power in explanation Y. This is fulfilled by assessing linear regression Y= ax + γ1y2 +…….. γk-1 yk + e and then testing, by a means of a F-test whether γ through {\displaystyle ~\gamma _{k-1}} γk-1 are zero. If the null-hypothesis that all {\displaystyle \gamma ~} γ coefficients are zero is rejected, then the model suffers from misspecification.

After the augmented Dickey- Fuller Unit root, Autocorrelation test and Heteroscedasticity test we will use ARDL method for calculating the long run Impact between mention variables. (Pesaran et al., 2001) to check the presence of the long run correlation among the variables. Autoregressive Distributed Lag Model (ARDL) Bounds testing methodology is a strong assessable technique in the assessment of level impact when the fundamental property of time series is totally I (0), and I (1) or mutually co-incorporated. Bound testing as an expansion of ARDL displaying uses F and t-statistic to test significance of the lagged levels of the variables in a univariate equilibrium alteration method when it is unclear if the data making process essential a time series is trend or first difference stationary. Here the ARDL technique will be use to explore the short-run and long-run relationship between variables.

Data Analysis

This chapter includes the results and estimations of the data. The first section consist of unit root tests results and the remaining sections includes diagnostic tests, empirical findings and interpretations.

Descriptive statistics

In table 2 given below shows the mean values log of carbon dioxide emission (LCO2), log of information and communication technology (LICT), log of Gross domestic product (LGDP) are 0.749910, 2.919542, 10.70245, respectively. While the standard deviation of LCO2, LICT, LGDP, are 0.109749, 0.718823, 0.992021, respectively.

Table 2: Descriptive statistics

	LCO2	LICT	LGDP
Mean	0.749910	2.919542	10.70245
Median	0.758650	3.267357	10.70222
Maximum	0.981820	3.821846	12.14898
Minimum	0.544419	1.802838	8.981093
Std. Dev.	0.109749	0.718823	0.992021
Observations	31	31	31

Source: Computed by authors based on time-series data from 1990-2020.

Unit root test & Phillips Perron test

Stationarity of the model at level

In table 3 given below shows the results of Unit root test at level and it was hypothesized that the data is non-stationary against the alternative hypothesis that the data is stationary. The results indicate that Carbon dioxide emission (CO2), Information and communication technology (ICT), Gross domestic product (GDP were not stationary at level.

Table 3: Stationarity of the model at level

Name of variable	I(0) (Level)	
	ADF Test Statistic	Critical Value (5%)
LCO2	-1.174299	-2.963972
LICT	-0.751332	-2.963972
LGDP	-1.671370	-2.963972

Note: ** & *** indicates the significance level at 5% and 10% stationary respectively.

Source: Computed by authors based on time-series data from 1990-2020.

Stationarity at 1st difference

The result of the unit root test at first difference is given in table 4 The results shows us that all of the variables (CO2, ICT, GDP) are stationary at first difference as shown by the ADF statistic values.

Table 4: Stationarity at 1st difference

	I(1) 1st Difference	
Name of variable	ADF Test Statistic	Critical Value (5%)
LCO2	-5.689488***	-2.967767
LICT	-4.375060***	-2.967767
LGDP	-5.531975***	-2.967767

Note: ** & *** indicates the significance level at 5% and 10% stationary respectively.

Source: Computed by authors based on time-series data from 1990-2020.

Summary of the ADF test

We apply the Augmented Dickey-Fuller test (ADF) for testing the stationarity of the variables are used in this study. In table 5 the results are presented. Augmented Dickey-Fuller test (ADF) is statistically insignificant at level for variables log of carbon dioxide emission (LCO2), log of information and communication technology (LICT), log of Gross domestic product (LGDP) are non-stationary at level. While all the variables are stationary at first difference. There is a mixed order of data stationarity so Autoregressive distribution lags (ARDL) is used in our research study.

Table 5: ADF test results

Name of variables	At Level	Variables	1st difference	Order of integration
LCO2	-1.174299	ΔCO2	-5.689488***	I (1)
LICT	-0.751332	ΔICT	-4.375060***	I (1)
LGDP	-1.671370	ΔGDP	-5.531975***	I (1)

Note: ** & *** indicates the significance level at 5% and 10% stationary respectively. Δshows the change

Source: Computed by authors based on time-series data from 1990-2020.

Phillips Perron test

The results of Phillips Perron test at level was hypothesized that the data is also non-stationary against the alternative hypothesis that the data is stationary. This results shows that Carbon dioxide emission (CO2), Information and communication technology (ICT), Gross domestic product (GDP), are not stationary at level which shows in Table 6 below

Stationarity of the model at level

Table 6: Stationarity of the model at level

	I(0) 1st Difference	
Name of variable	**PP Test Statistic**	**Critical Value (5%)**
LCO2	-1.130947	-2.963972
LICT	-0.902530	-2.963972
LGDP	-1.230966	-2.963972

Note: ** & *** indicates the significance level at 5% and 10% stationary respectively.

Source: Computed by authors based on time-series data from 1990-2020.

Stationarity at 1st difference

The result of the Phillips Perron test at first difference is given in table 4.3.2 shows us that all of the variables (CO2, ICT, GDP,) are stationary at first difference as shown by the Phillips Perron test statistic values.

Table 7: Stationarity of the model at level

	I(1) 1st Difference	
Name of variable	**PP Test Statistic**	**Critical Value (5%)**
LCO2	-5.687072***	-2.967767
LICT	-4.375060***	-2.967767
LGDP	-5.547906***	-2.967767

Summary of the Phillips Perron test

We apply the Phillips Perron test (PP) after Augmented Dickey-Fuller test (ADF) for testing the stationarity of the variables used in this study. In table 4.3.3 the results of the test are show that Phillips Perron test (PP) is statistically insignificant at level for variables LCO2, LICT, LGDP are non-stationary at level. Although all the variables are stationary at the first difference. There is a mixed order of data stationarity so Autoregressive distribution lags (ARDL) is used in our research study.

Table 8: Phillips Perron test Result

Name of variables	At Level	Variables	1st difference	Order of integration
LCO2	-1.130947	ΔCO2	-5.687072***	I (1)
LICT	-0.902530	ΔICT	-4.375060***	I (1)
LGDP	-1.230966	ΔGDP	-5.547906***	I (1)

Serial Correlation test

We apply serial correlation after unit root test in the table 4.4; show the probability value of serial correlation is 0.2876 which is greater than 0.05 which means there is no autocorrelation problem in the model.

Table 9: Serial Correlation result

Test Statistics	Probability Value
Serial Correlation	0.2876

Lag length criterion

Optimum lags selection of the models

The first stage of ARDL technique, we estimated the lag order through VAR techniques. On the basis of minimum value of AIC and SC, best fitted model was selected. In the given results in the Table 4.5 Schwartz information Criterion (SC) is the best fitted model. The order of the lag length is "1" model in this study.

Table 10: Optimum lags selection of the model

Optimum lags selection for model		
Lags	**AIC**	**SC**
0	20.586	20.937
1	16.937	15.523*
2	13.433*	17.324

* indicates lag order selected by the criterion
AIC: Akaike information criterion
SC: Schwarz information criterion

ARDL Bounds Testing

In Table 11, shows the estimated value of ARDL bound test, the lower and upper bound values are at 1 percent level of significance (3.29 and 4.37). So the F-statistic (7.732692) is greater than the upper bound value, On the basis of statistically significant value of the F-statistic we reject our null hypothesis that support our all hypothesis that there is no cointegration among the variables (Pesaran et al., 2001). The R-squared are 0.99 which means that 99 percent variation comes in dependent variable from the independent variables and remaining 1 percent variations are due to error term in the model the p (F-statistic) values is (0.003651) which is less than 0.05 or 5% so we reject the null hypothesis and the overall model is significant. The Durbin-Watson statistic value of model is 0.0230 which is between the values 1.7 to 2.2 so no autocorrelation problem exists which are shown in table 11.

Table 11: ARDL bound test

Test Statistic	Value	Critical Value		
		Significance	**I(0), Lower Bound**	**I(1), Upper Bound**
F-statistic	7.732692	10%	2.21	3.09
		5%	2.56	3.49
		1%	3.29	4.37
R-squared	0.99			
Adjusted R2	0.950411			
Durbin-Watson tatistic	0.0230			

Long-run ARDL Estimates

Table 12 shows the ARDL estimates where the coefficient of ICT is negative which reveals that 1% rise the ICT will reduce CO2 emission by -14.2590 %. Our results are consistent with those of (Khan et al., 2020; Shehzad et al., 2020). The coefficient of GDP positive it indicates that 1% surge the GDP lead to surge CO2 emission by 6.1212%. Our study results are similar to those with (Khan et al., 2020; Shabani et al., 2021).

Table 12: Long-run ARDL estimates

Long run estimates				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LICT	-0.142590*	0.075510	-1.888359	0.0736
LGDP	0.061212**	0.027149	2.254677	0.0355
LGDP2	0.110845	0.037651	1.500555	0.4012
C	-2.212443	1.721994	-1.284815	0.2135

Note: ** & *** indicates the significance level at 5% and 10% respectively. CO2, ICT, GDP, CEC and INF represent Carbon emission, information and communication technology, gross domestic product, coal energy consumption and infrastructure (Transport) respectively. ECM represent error correction model. Model Selected: ARDL (1, 1, 1, 1, 1). Regressand is CO2.

Source: Computed by authors based on time-series data from 1990-2020.

Short-run ARDL Estimates

In table 13 shows the result of short-run ARDL estimation. The short-run coefficient of ICT, GDP, has negative effect on CO2 emission, The ECM coefficient value was found to support the theory (with a negative sign) and found 61% percent annual convergence from short-run to long-run equilibrium for the selected variables. In the long run the square of GDP is insignificance, while significance in short run we found that in short run environmental Kuznets curve exist in Pakistan.

Table 13: Short-run ARDL estimates

Short run estimates				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Δ(LICT)	-0.027427	0.037121	-0.738875	0.4686
Δ(LGDP)	-0.008803	0.048248	-0.182451	0.8571
Δ(LGDP2)	0.110845***	0.037651	2.943993	0.0083
ECM(-1)	-0.615118	0.174870	-3.517570	0.0022

Note: ** & *** indicates the significance level at 5% and 10% respectively. CO2, ICT, GDP, CEC and INF represent Carbon emission, information and communication technology, gross domestic product, coal energy consumption and infrastructure (Transport) respectively. ECM represent error correction model. Model Selected: ARDL (1, 1, 1, 1, 1). Regressand is CO2.

Source: Computed by authors based on time-series data from 1990-2020

Robustness Analysis Test Results

As shown in Table 4.6, ARDL robustness tests are used to investigate the CO2 emission models' validity, reliability, and efficiency. Autocorrelation/serial correlation and heteroscedasticity are not a problem in the ARDL model, according to diagnostic tests. The Jarque–Bera and Ramsey RESET tests for model normality and stability are also used to determine whether the model is normally distributed and stable. So we conclude that all residual diagnostic is statistically insignificance, therefore our model is error free.

Table 14: Robustness analysis

Test	**F-statistic**	**Prob**
Jarque–Bera test for normality	0.878995	0.5773
LM test for Autocorrelation	4.133005	0.3315
ARCH test for Heteroscedasticity	0.617636	0.3758
BPG-LM test for Heteroscedasticity	0.542908	0.7636
Ramsey RESET test for stability	2.138812	0.2662

Source: Computed by authors based on time-series data from 1990-2020.

Findings, Conclusion and Suggestion

Findings

The goal of this research is to explore the effect of macro-economic variables (ICT, GDP,) on CO2 emission in Pakistan for a long run and for short run. This research study concludes that the macro economic variables have a significant impact on CO2 emission for long run also for short run in Pakistan. For this purpose, a time series data of 31 years, ranges from the period of 1990 to 2020. The data was collected from source like world development indicators (WDI). To achieve objective of the study, a model is constructed to estimate the relationship of carbon emission and information and communication technology, gross domestic product, For long run relationship ARDL model is used among the variables.

Conclusion

The main objective of this research study is to test the relationship among information and communication technology, gross domestic product, and emission of CO2 in Pakistan from 1990 to 2020. Stationarity of each time series was checked through Augmented Dickey–Fuller (ADF) Unit Root Tests. The outcomes of the Augmented Dickey–Fuller (ADF) Unit Root Tests indicated that all the variables are non-stationary at level without infrastructure (Transport). while stationary at first difference and non-stationary on the second difference. Autoregressive distributed lag (ARDL) technique is apply for testing long-run, short-run correlation among the mention variables. Long run ARDL technique results indicated that GDP have a positive impact on CO2 emission in Pakistan. While Coefficient of ICT shows a negative impact on the CO2 emission in Pakistan for both short as well as long run.

Suggestion

Pakistan needs to implement environmental policies on industries to install new technologies in our industrial sector that will help in reduction of environmental pollution.

On the basis of our conclusions the study has following recommendations. The path to maintainable environment may be related to the development of information and communication technology (ICT) sector in Pakistan, as with higher growth rate (GDP) more effective procedures will be used that will take care of the atmosphere. Furthermore, policies must be designed to inspire basic changes in the economy which motivates shift from the industrial sector to services sector (less energy-intensive).

This is the correct time for policy makers to carry an Advance infrastructure (Transport) Strategy for Pakistan which will reduce environmental pollution and manage the increasing burden on roads. The government authority must first address the country's electrical energy crises so people can use electric and hybrid vehicles. Investors should present hybrid automobiles and other vehicles and also electric bicycles in Pakistan.

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