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Impact of Climate Change on Electricity Consumption in Pakistan: An ARDL Approach

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Abstract

Numerous communities worldwide may be impacted by climate change, which could have major repercussions. One of the nations that has been most negatively impacted by climate change is Pakistan. Every economic sector has been impacted by these climate changes, but the energy sector has been particularly hard hit. In this background, the aim of this study is to find the impact of climate change on electricity consumption, for this study we have annually data of Pakistan from 1971-2017. The project reviews the trend of climate variation for the last few decades. For estimation, the data have been taken from World Development Indicators (WDI), Water and Power Development Authority (WAPDA) and Climate Knowledge Portal World Bank Group. By using ARDL model, and taking data on annual basis, the nexuses between dependent and independent variables has been found. The study revealed significant results and recognized that climate has a substantial impact on nation's energy demand. According to the results it is suggested that the government should take measures to overcome the crises and make strategic policies which can turn the crises into opportunities for bringing around structural changes in long run in the economy and in society.

Key words: Greenhouse Gases, Carbon Dioxide, WAPDA, ARDL

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1. INTRODUCTION

Climate refers to the average weather of a region or area over an extended period of time. It is affected by many biotic and abiotic factors. Biotic factors are transpiration, photosynthesis, decomposition and abiotic factors are factors such as latitude, altitude, ocean currents, evaporation, humidity, temperature, topography, air pressure, volcanic activities. There is a difference between climate and weather. The state of the atmosphere at a specific time and location in relation to variables like temperature, moisture, pressure, etc., is known as the weather. While climate reflects long-term atmospheric conditions, weather reflects short-term ones. Climate has four-dimensional and time centered components which contains many different sorts of weather seasons, their cyclicities, concentrations, and nature of vitality.

As reported by Working Group II of the Intergovernmental Panel on Climate Change (IPCC); Climate change imply that any adjustment in the atmosphere over the long haul, regardless of whether it is because of characteristic inconstancy or because of human movement. Impacts of climate variation are intense droughts, rising sea levels, storms, melting glaciers, floods, earthquakes, cyclones etc. Climate shift is an immense challenge facing mankind today. Increase in emissions of carbon dioxide, deforestation, global warming, ozone layer depletion etc leads to huge climatic disasters. These ozone depleting substance discharges have expanded the nursery impact causing ascend in temperature of earth's surface. It is the natural phenomenon and undeniable, which is the single largest environmental hazard facing the planet.

Electricity consumption refers to the type of energy consumption that utilizes electric power. Electric energy consumption is the real energy demand placed on available electric supply. After defining climate change and electricity consumption the key purpose is to understand the nexus between them. But there are some variables which affect both electricity consumption and climate change. Take the example of precipitation level and rainfall, triggered by climate instabilities are positively correlated with electricity generation. Global warming has very little consequence on the production of hydroelectricity directly. It affects the hydrogeneration slowly by drawing changes in climate over a long period. Generation from hydroelectric plants is affected by climate and climate variation. (Munoz & Sailor 1997).

Pakistan being a climatically diverse country is mostly subjected to the various types of events like floods, air pressures, precipitation, droughts etc. Being a low carbon emitter country, ranked 135th while considered among the top 10 nation that are affected by climate changes. Pakistan is faced with an unprecedented level of climate changes and its effects on its economy (German Watch, 2015). According to Wheeler (2015), natural phenomenon, human behaviors, discharge of ozone harming substances, for example, methane, CO_2 and alteration in land use can cause climate change. Variations in climate bring changes in weather conditions and durations by creating warmer temperatures, change in rainfall pattern, rise in sea levels and increased frequency and severity. High variability in precipitation may result in floods. Pakistan faced many devastating floods in 2011,2014 and 2015. Though Pakistan itself emits very few of the greenhouse gasses, yet it is one of the most highly affected nations of the globe as a result of global warming. Table 1 presents the extreme weather events in Pakistan.

Temperature is also an upsetting variable which immensely alters the electricity consumption while rise and fall in temperature patterns also leads to climate variations.

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Pakistan which is an already resource stressed country has been crippled by the process of global warming because in the World, Pakistan located in the area where the fluxes in temperature caused by climate changes is above the world average temperature referred as a warm climate (Rasul & Ahmad 2012). Because of climate change, not only rise in average temperature comes about but the ranges of temperature are also expanded. At the end of the century, about 3.3-degree centigrade average rise in temperature for the region of South Asia has been caused annually (IPCC).

Pakistan is facing problem of severe energy calamities in the form of electricity shortage. There was an immense gap in the year 2011 between demand of electricity and supply. Pakistan fell short of supply ranging between 5000 MW to 7000 MW (Malik 2012). During the most recent couple of years, Pakistan power deficiency has been increasing day by day. In June 2013, electricity produced was 12150MW while electricity shortfall reached 4250 MW with the demand standing at 16400MW (PEPCO). Table 2 below shows a gap between supply and demand of electricity in Pakistan. Further, this gap is also represented in figure 1.

Table 2: ***Gap between firm Supply and Peak Demand for Pakistan 2002-2020***

S. No.	Year	Firm Supply(MW)	Peak Demand(MW)	Surplus/Deficit
1	2002-2003	14336	13071	1265
2	2003-2004	15046	13831	1215
3	2004-2005	15082	14642	440
4	2005-2006	15072	15483	411
5	2006-2007	15091	16548	1457
6	2007-2008	15055	17689	2634
7	2008-2009	15056	19080	4042
8	2009-2010	15055	20584	5529
9	2010-2011	15430	21086	5656
10	2011-2012	14483	21536	7053
11	2012-2013	16846	21605	4759
12	2013-2014	18121	23505	5384
13	2014-2015	18482	24757	6275
14	2015-2016	20303	25666	5363
15	2016-2017	23445	27185	3740
16	2017-2018	28751	28678	73
17	2018-2019	33545	30154	3391
18	2019-2020	35590	31625	3965

Source: PPIP, Ministry of Water and Power National Electric Power Regulatory Authority (NEPRA) 2016.

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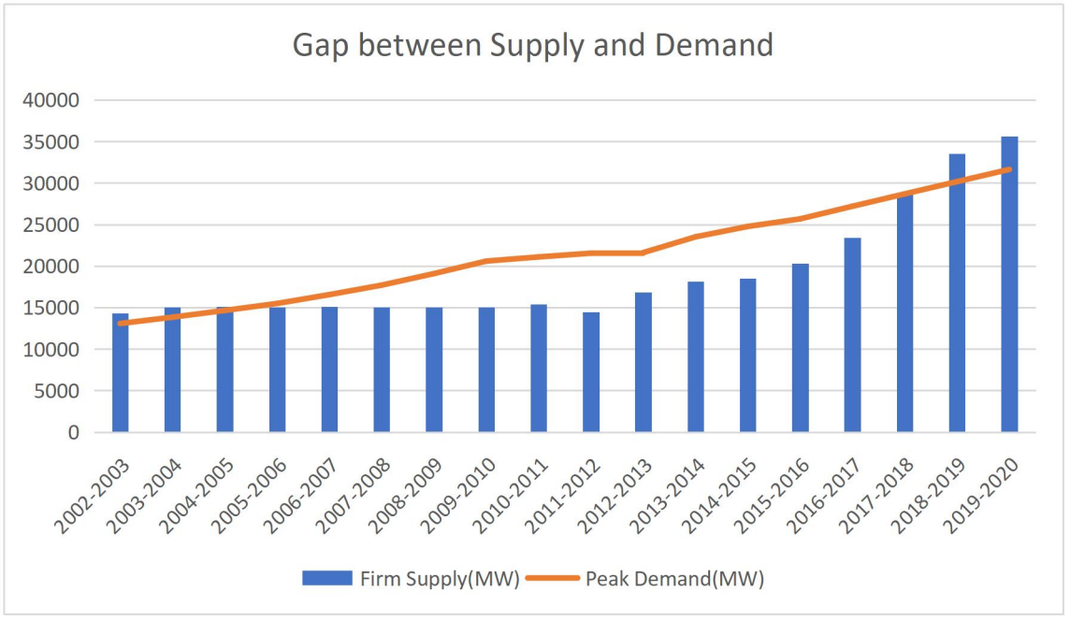

Figure 1. Gap between Electricity Supply and Demand in Pakistan

Pakistan power system is characterized by huge gap between supply and demand. If we think about the power creation and utilization levels it can undoubtedly be seen that in Pakistan power creation consistently stayed short to adapt the necessary interest. Figure 1 expands that from 2002 this hole exists which enlarged with the progression of time and consumed further until 2019. In Pakistan, electricity is among the most used energy resources. Electricity is used for various purposes in residential, industrial, commercial and agricultural sectors. Pakistan which is itself a resource strained nation has been paralyzed by the process of global warming because in the World,

Electricity demand is elastic to income and price level. A substantial upsurge in electricity demand in Pakistan has been noticed due to industrial development, urbanization and rural electrification. Chaudhry (2010) found that electricity consumption at both national and household level rises in real per capita income in Pakistan. An output function analysis showed that price elasticities affect the energy utilization and cost of production. To measure the income level, GDP per capita is taken as an indicator. Many studies (e.g, Jamil Ahmad, 2021; Javid and Qayyum, 2013) revealed that income and electricity consumption positively related with each other. Previous studies indicated a strong connection between price and consumption of electricity (e.g Inglesi Lotz; Jamil and Ahmad etc). These studies emphasized that price and electricity consumption are negatively correlated. As the prices increase there will be persistent decrease in consumption pattern. However, there are restricted and no alternatives for buyers to change from power to different wellsprings of energy like oil, gas and so on because of power costs (Javed & Qayyum 2013).

GDP is the most important measure of economic performance. Strong positive nexus has been depicted between Gross domestic product development and development pace of power age. During the time of low development pace of power age, GDP development rate stays low. Development pace of power age has declined from 11.8% to 1.5% when GDP rate falls from 5.8% in 2006 to 3.6% in 2013. Economic growth badly affected by power shutdowns and load shedding. It is assessed that around 2% loss in GDP

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occur due to these blackouts (Abbasi 2007). Growth is a crucial macroeconomic goal as it facilitates higher standards of living. Chen et al.(2007) and Gosh (2002) claim that electricity consumption is affected by economic growth. Economic growth indicates development in commercial and industrial sector, growth in urbanization and innovation where power has been exceptionally utilized. Electricity utilization in vehicle and agribusiness area has likewise speeded up to stay up with monetary development of the nation. The use of more electric appliances and machinery has been increased by household sector due to rise in disposable income. Therefore, direct relation has been revealed between electricity consumption and economic growth because energy utilization is straightforwardly connected with mechanical creation, financial development and way of life in Pakistan. A continuous increase in economic growth results in increasing the consumption pattern in general and electricity in particular.

Electricity has been considered as the backbone for financial thriving and progress subsequently it assumes crucial job in financial turn of events. With the progression of time as quick turn of events and mechanical developments has occurred, the use of energy has additionally mounted. Consequently, interest for energy has expanded over the long run. Study confirmed that the financial development of the nation has exhibited to be one of the fundamental jumpers of power utilization. (Inglesi & Blingnaut, 2011). Economic growth is highly influenced by load shedding and power shutdowns. Power calamities and load shedding act as a main damage to economic growth by causing poverty, unemployment, inflation and trade due to which economic development is affected (Kessides, 2013). Electricity is an engine of growth at both domestic and global level. Power crises has a huge impact on agriculture sector, ecosystem, industrial sector and overall economy. Pakistan industrial sector has been mainly ruined by the shortage of power. Most of the industries and factories have been closed due to energy shortfall. Because of this problem around 7.5 percent of labor force has been forced out from their jobs and 40 percent of factories and industries have been closed. Pakistan has been going through a worse situation of energy crises (PEPCO).

In most of the studies, only temperature has been taken as an explanatory variable to check the relation between climate change and the energy consumption. However, other studies have been conducted to find the impacts of climate change on electricity consumption for Pakistan [Ali, et al. (2013)]. Climate change projections for Pakistan indicates that there will be an increasing pressure on the consumption and demand of electricity for many sectors.

1.1 Electricity Sector in Pakistan

In 1947, at the hour of freedom, Pakistan acquired 60 MW power age ability, which could oblige the requirements of the entire populace. The country expanded the power generating capacity to 119 MW by the year 1959. Electricity comprises one of the most valuable components of infrastructure and plays a vital role in development and national growth. Electricity is an engine of growth at both domestic and global level. However, with the achievement of KESC in 1952 and the establishment of an autonomous and statutory body i.e, WAPDA took place which is responsible for the management of water resources to boost up the agro-economy of the country. Due to rise in number of electrified villages from 609 to 1882, WAPDA extended the generating capacity to 636 MW. Pakistan's power sector flourished rapidly and increased the generation capacity from 1331 MW in year 1970 to 3000 MW in 1980 followed by further growth to 7000 MW in 1990-1991. Electric supply

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has lagged demand since the early 1990's. Despite the fast growth of the energy sector, energy demand has been outpaced by aggregate supply. The growing rate of rural electrification, urbanization and industrialization also puts a premium on demand for electricity (9-10% per annum).

The power sector of Pakistan has been important to manage required capacity due to poor governance, inappropriate tariff structures, institutional weaknesses and poor load management strategies to manage power shortfall. Reforms of power sector through reorganizing and deregulation is high on the agenda of Government of Pakistan. This shortfall leads to the private sector initiatives in power development and to help the country's future power need. Poor performance of public sector, market price, continuously constricting budget and necessity to make tariff free subsidies provide incentive for mobilization of resources, enhancing productivity through the integration of private sector to reduce the pressure on budgetary resources to satisfy consumer aspirations at reasonable tariff. In 2000, WAPDA unbundled into 14 independent units. Four thermal generating companies, nine distribution companies and a transmission and distribution company. The main source of electricity in Pakistan are Water and Power Development Authority (WAPDA) with consumer base of over 10 million, Karachi Electricity Supply Company (KESC) with the consumer base of 1.5 million, Pakistan Atomic Energy Commission (PAEC) and number of Independent Power Producers (IPP).

As per preceding discussions, it is concluded that electricity consumption and weather variations are commonly related with each other, but consumption is badly affected by many climatic factors which will upset the Pakistan's economy. In Pakistan there are many factors like carbon dioxide emission, precipitation, temperature, floods, droughts, air pressure and so on which has a negative impact on economy, industrial, commercial, and residential sectors in Pakistan. All these issues are the main hurdles to meet the need for electricity. Therefore, the study explore What is the impact of climate change on the demand for electricity in Pakistan? and What will be the economy-wide demand for electricity in the coming years? So, the main objectives discover the impact of climate change on electricity consumption in Pakistan.

The significance of this study shows how this study is different from other studies. Most of the studies used only temperature but in this we have used many other climatic variables. We have used an econometric model which includes different variables like temperature, GDP, rainfall, carbon dioxide emission etc. We will find the effect of these variables on electricity demand which will affect the Pakistan economy and empirical analysis of income and price elasticities.

2. LITERATURE REVIEW

For researchers, relationship between climate change and energy demand became the area of interest mainly in late 1980's. Under the situation of bending over of corbon emissions, Cohen and Bhartendu (1987) revealed the adjustments in power utilization in Ontario, Canada. The study found positive relation of carbon emissions to cooling requirements while negative relation with heating requirements of households by integrating population weighted heating and cooling degree days through regression analysis. According to the IPCC assessment report 5, carbon dioxide emissions from the energy sector will increase from 14.4 giga tones ($GtCO_2$) per year in 2010 to 24-33 $GtCO_2$/year by 2050. The carbon dioxide emissions in 2014 were approximately 40% higher than in the 1800s. This equates an annual increase of two parts per million (ppm) in the past ten years.

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Metz et al. (2007) stated that global climate change is generally brought about due to increase in GHG concentration in atmosphere. The transcendent wellspring of GHG emanations in environment is fossil fuel combustion which contributes about one third of the total global GHG emissions. CO2 concentration reached about 388 ppm in August 2010, showed an increase by nearly 100 sections for each million (ppm) by volume as contrast with pre-mechanical levels. Without approaches throughout the following 20 years, worldwide GHG outflows are projected to increment from 25% to 90%.

Sailor and Munoz (1997) deduced the impact of climate variability on hydroelectric generation by regressing the hydrogeneration on climate variables such as snowfall, total precipitation, soil, moisture, and evaporation on the watershed in which the plant is located. This scenario found that shifts in hydroelectricity generation are triggered by climatic unpredictability like global warming, greenhouse effects, temperature rise and fall, precipitation levels etc. The energy sector, particularly production area, is one of the highly responsive sectors to weather changes because electricity cannot be stored. It indicates that produced electricity must be instantly used. Further, good quality models are needed to forecast future consumption. Tariq & Athar (2009) examined that weather change is major problem which can affect the life on earth. Weather changes result in temperature rise or fall which may affect the ocean levels. Climate change effect different sectors of the economy, specifically agriculture and energy. The evaluation of study is based on the effect of climate change on energy sector in Pakistan from last two decades. The climate change effect on energy sectors may be in the shape of decreasing the hydro power generation and its efficiency. From General Circulation Climate Models, Hadley, et al. (2006) estimated the uncertainty between climate change and energy demand in US. Study revealed that the variability in climate may alter energy demand and carbon emission increases through electricity generation responsive to climate change. Development in populace and expectations for everyday comforts is prompting increment in force utilization, transportation which thus expands the outflow on carbon dioxide and other greenhouse gases (GHG).

Energy consumption will rise in future under immense climatic changes. Morrison & Mendelsohn estimated that due to 2-degree centigrade average temperature rise in climate in US, energy costs would increase almost by $6 billion in 2060. The study evaluated that US electricity sector could require investment of $200-300 billion under the climatic change scenarios to increase the capacity accumulation requirement by 14-23% as compared to non-climate change scenarios (Linder 1990). An increase of 1 degree centigrade in temperature increases the energy consumption for cooling requirements by 28% whereas decreasing the energy use for heating requirements by 10% (Cartalis et al, 2001). There will be a considerable drop in heating requirements as the range and average temperature extended throughout the world while the need for cooling stuff will be increased (Howden & Crimp 2001). Due to industrialization, massive urbanization, rural electrification, growth in agriculture sector, rising per capita income and rapid growth in domestic consumption will expend the demand of electricity. Because of poor future planning and forecasting, upgrading the existing generation plants and set up new electricity generation units failed to meet the need of electricity (Kessides 2013). Widening in temperature boosted the electricity demand. Study examined that average summer peak loads increased by 10% with up rise in temperature about 4%, in Israel (Segal et al., 1992). Due to climatic variations, in Massachusetts, US, increased energy demand may go up to

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40% due to climate change over the year 2030 (Amato et al. 2005). Energy area is one of those areas which is highly affected by weather patterns. These variations affect both the demand and supply sides. Supply side mostly concern with the area which is dependent to hydropower plants. Imbalances in supply and demand of electricity can be produced by long-term change in weather variations. Study forecasted that due to climatic variations, load on energy requirements will increase from 65-75 MW in year 2020 to 85-95 MW (shows 9-10% upsurge per annum). in year 2030 in Cyprus (Zachariadis 2020).

Temperature and precipitation are two key meteorological factors which determine the climate of any region. Any persistent change in both or one of them with respect to long term mean or normal values leads to the climate change of that region. Guttman (1983) investigated the variability of population-weighted seasonal heating degree days for 48 states in United States. He determined that population demand for cooling increased as compare to heating demand. Results assumed that the estimate of future heating energy demand depend on the variability of climate not only rely on historical averages. Under global warming, Rosenthal, et al. (1995) observed a decline in warming and freezing energy wants in US for commercial and residential segments. This study involves two step methods. In first step the sensitivity of electricity demand to temperature rise is estimated while in other step these regarded sensitivities are projected alongside environmental change to gauge future energy interest. Analysis assessed that one degree warming in the US would reduce primary energy use by 0.70% in 2010 relative to non-warming scenario and energy expenditure by $5.5 billion. Valor and Meneu (2001) used statistic models to designate a daily air temperature behavior. The study has been conducted in Spain which disclosed strong seasonal behavior of temperature in terms of heating degree days and cooling degree days. They found that electricity demand is reactive to the temperature change which is considered most substantial weather variable. Electricity demand, price and volumes of electricity are extremely influenced by temperature. Authors found non-linear relation between energy demand and temperature which expressed an increase for electricity demand both for heating degree days and cooling degree days correspond to the cooling requirements in summer and for heating purpose in winter season. This study not only confined to value the weather derivatives but also use these estimations in future for managing economic activity risks like rise in electricity demand, increase in oil and gas prices etc.

Bessec and Fouquau (2008) in the time period 1985 to 2000 via monthly data examined the temperature-electricity demand nexus. They conducted this study for 15 European countries and analyzed the threshold temperature as well as the relationship between the above two variables for those countries by using panel smooth transition regression model (PSTR).

Amato, et al. (2005) used a procedure to recognize the regional energy demands to climatic deviation in the Federation of Massachusetts by relapsing month to month per capita energy utilization on temperature, HDD, CDD, pattern in CDD and HDD, cost of power and long stretches of light and so forth The investigation assesses the temperature affectability of private and territorial area for power interest. From results, positive and huge effects of HDD and CDD on power request was noticed and based on these discoveries future energy requests to climatic alterability was additionally outlined. To anticipate the yearly and pinnacle ascend in power interest from 2005-2099 for California, Franco and Sandstad (2008) utilized the atmosphere projections by utilizing the nexus of

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hourly power burden and normal every day temperature longer than a year from three General Circulation Models (GCMs). Literature anticipated significant rise in energy demands to the temperature by 3.1 % in the time period of 2005-2034, 8.1% in 2035-2064 and 1.8% in 2065-2099. In order to examine the possible trends in the temperature dependence of electricity demand for Netherland, Hekkenberg et al (2009), used daily data over the time period 1970-2007. Analysis illustrated that in summer months mostly in month of May, June, September ,October and during the summer holidays electricity demand is highest in Netherland. This significant boost in electricity demand for summer season leads a signal to raise the future expectations for additional peak loads of electricity consumption under the influence of climate change.

Moral-Carcedo and Vicens-Otero (2005) by utilizing every day information utilized the limit relapse model (TR) and the strategic smooth change relapse (LSTR) model to fabricate the connection among temperature and power interest in Spain for the time frame of 1995-2003. Assessment sorted out that the connection between power interest and temperature is non-direct and the non-linearity is pondered the limit temperatures. By taking month to month time-arrangement information which goes from 1983 to 2012 and using smooth transition regression model (STR), Liao, et al. (2018) predicted the electricity consumption and temperature relationship by building non-linear econometric models in Taiwan. By using this model, the author estimated the six threshold and average temperatures. The value of average temperature was 26.384 degree centigrade while the threshold temperature ranges between 25.364 degree centigrade and 27.156 degree centigrade. All these stuffs provided framework to the policy makers of Taiwan's in order to find the future demand and to meet the demand. This study showed significant results and provide approaches to moderate the impacts of climate fluctuations on consumption of electricity. By mean of key measures of temperature i.e. HDD's and CDD's, all the demand and supply of electricity can be detected which is inclined due to climatic deviations. By HDD's means that entire negative deviations in a given time span from the actual temperature which is measured to the base temperature but CDD's is opposite to HDD's. CDD's refer to the total of positive deviation in a given time frame from the average temperature to the base temperature. Sailor and Munoz (1997) established and related two statistical models based on different sets of monthly independent variables, one with derived variables measuring heating and cooling degree days and one with "primitive" variables, applied to eight US states. Derived variables refer to HDD and CDD while primitive variable means precipitation, snowfall, moisture, rainfall etc. Better results for electricity yielded by using degree day model while the primitive variables were desirable for natural gas.

Iqbal (1983) estimates the elasticities of price and income for residential electricity and natural gas demand. By using OLS and GLS method, findings figured out that electricity demand is only income elastic although in case of natural gas both pay (income) and value (price) flexibilities are measurably critical. As per Khan and Usman (2009), pay and power costs are showed up as significant determinants of power request work which is assessed through Johansen cointegration and ECM through VAR system for the stretch of time 1972-2007. Examination uncovered that power go about as both pay and cost inelastic which reflects power as a need. Because without electricity no one can think his/her life now a days.

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Energy assumes a urgent part in upgrading financial turn of events. It has become a motor of financial development at neighborhood and worldwide level. Power is required worldwide for encouraging and supporting improvement measures. Hu and Lin (2008) noticed the non-straight cointegration among GDP and disaggregated energy utilization for Taiwan. This audit shows that when an appropriate edge is reached, the change cycle of energy utilization toward balance is profoundly consistent. Shahbaz, et al. (2012) examined that economic development boosts by energy consumption. Electricity is the main input for economic growth. By applying ARDL method, the link between GDP and electricity consumption has been explored over the time period of 1972-2011 by using Cobb-Douglas production method. Javid and Qayyum (2013) inspected the relationship between electricity consumption, prices of electricity and economic growth for industrial, residential, agricultural and commercial sectors. The study discovered the electricity consumption function over the time period 1972-2010 for Pakistan by means of time series procedures. Through this study, the authors found a nonlinear, deterministic but stochastic nexus between electricity consumption and GDP. The study disclosed the fact that electricity is vital to both the production and consumption of goods and services within the economy. The electricity demand throughout the whole economy raised with the increasing populations, industrial development, massive use of electrical appliances and intensive urbanization.

For Pakistan literature about energy demand and climate change nexus largely lacks. Only few studies have been done to find the electricity demand function by taking temperature as an explanatory variable[Jameel and Ahmed(2011)] but Ali, et al. (2013) tried to explore the link between climate variability and its impact on electricity demand and consumption. This study deduced the relationship by using ARIMA model between monthly extreme temperature index in Pakistan and electricity demand and also forecasted the electricity consumption due to rise in temperature in future. The forecast value depicts that electricity demand increases due to rise in temperature with the passage of time. Monthly data exhibited growth in electricity consumption for summer season but decline in winter season.

Being climatically diverse country, the current issue required more consideration because this area remains yet to be explored. However, this study bridges the gap for Pakistan by examining the relationship between electricity demand and climate change.

3. DATA AND METHODOLOGY

For achieving the objective, we need to develop an econometric model which verifies the relationship between climate variability and electricity consumption. For such purpose we have applied different estimation techniques. In this study electricity consumption is used as dependent variable while the independent variables are temperature, rainfall, carbon dioxide emission, and GDP . Thus, the general electricity demand function is given as follows:

Electricity demand = f (average annual temperature, average annual rainfall, carbon dioxide emission, GDP)

More specifically, an econometrics model is given as follows:

$$EC_t = \beta 0 + \beta 1 Temp_t + \beta 2 Rainfall_t + \beta 3 CO2_t + \beta 4 GDP(PC)_t + \mu t \ldots\ldots(1)$$

Where,

EC_t = Electricity consumption/demand

T=temperature

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R=rainfall
CO_2=carbon dioxide emissions
GDP= GDP per capita
μ_t = error term
In Eq. (1) EC shows the electricity consumption measured in (kWh) per capita which is dependent variable and temperature is measured in ˚C, rainfall is measured in mm , CO2 shows the carbon dioxide emission, GDPPC stands for GDP per capita at constant price in US dollar. Here in the equation the term t expresses the time period, which is from 1981-2020, β_0 is the intercept while $\beta_1,\beta_2,\beta_3,\beta_4$ are the coefficients of temperature, rainfall, CO2 emissions, GDP respectively. Various tests are applied to examine the relationship between the dependent and independent variables.

3.1 Data and Data Source

Different variables are used to investigate the nexus between electricity consumption and climate variability. The statistical estimate consists on time series data and from the duration of 1981-2020 and data is of secondary nature. Data on electricity consumption, GDP per capita (constant US$), CO_2 emission has been taken from World Development Indicators (WDI).For electricity consumption, we have used electric power consumption (kWh) per capita. For country level analysis, annual data on average temperature and rainfall for this time have been taken from Climate Knowledge Portal World Bank Group.

3.2 Estimation Techniques

The dependent variable in our model is electricity consumption in Pakistan, which is regressed on temperature, GDP, rainfall, GHG to find the relationship between them. As electricity demand does not depend only on temperature, but also other variables should be included in the analysis such as price, GDP rate, population (Jamil and Ahmad, 2021). It is claimed in literature that there is a two-way causality between temperature and electricity demand Lee and Chiu, 2011). A rise in temperature causes an upsurge in electricity demand while on other hand growth in power generation from many sources to meet increased demand may bring about climatic effects such as uplift in average temperatures through greenhouse gas emissions (Climate and Electricity Annual 2021). In case of analysis on Pakistan as a whole, 47 years data on electricity consumption are used which is a period long enough to merit consideration of climatic effects on consumption pattern. The study uses ARDL estimation technique and EViews statistical software for the computation of empirical results. Since the data are of time series nature, therefore, various data characteristics shall be studied and based on those results econometric estimations employed.

4. RESULTS AND DISCUSSION

The table below shows the relationship between impacts of climate change on electricity consumption. The estimated result shows that temperature have negatively significant, which means that increase in temperature will lead to reduce electricity consumption in developing countries like Pakistan. The reason behind this is shortage of electricity during summer season. Rainfall have positively significant but after some lags it will be negatively significant. Co2 emission have also negatively significant at 10% level. While GDP per capita have positively significant, which indicates that increase in GDP per capita income of individual will lead to increase electricity consumption. In terms of the diagnostics, both the short run and the long run results are stable in the model. It shows that the models are stable as it converges towards the long run equilibrium which is reflected in the

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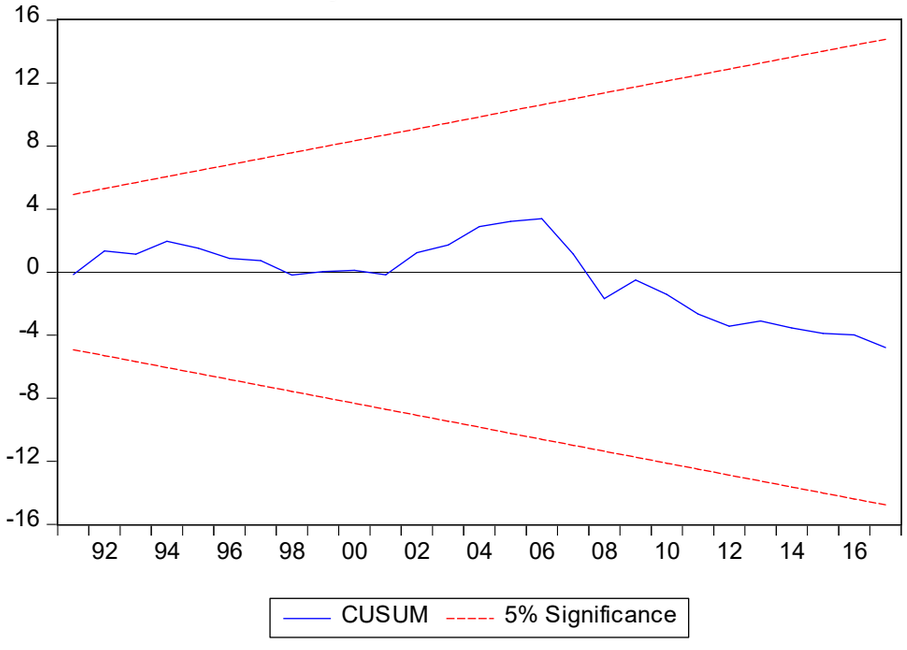
fact that the ECM terms are negative and significant. The Lagrange Multiplier (LM) indicates that the model has no issue of serial correlation problem, while the CUSUM (CSM) and CUSUM of Square (CSM2) indicate the stability of the model. While the value of the adjusted R square is reasonable.

Table: 1 Empirical Results for Pakistan

Linear ARDL Model Estimates						
Panel A: Short Run Results						
Lags	0		1		2	
Δ Temp	-1.38(-0.46)		6.09**(1.89)			
Δ Rainfall	1.07*(2.64)		0.52(1.46)		-0.71**(-1.83)	
Δ CO2	117.4(1.40)		-138.6**(-1.83)		-128.09**(-1.98)	
Δ GDP (PC)	0.68*(4.60)		0.34(1.49)		-0.20(-1.44)	
Panel B: Long Run Results						
Constant	Temp	Rainfall		CO2		GDP (PC)
-156.62(-0.39)	-32.21(-1.55)	2.61(1.20)		1009.35*(5.54)		0.26*(3.22)
Panel C: Diagnostic Results						
F	LM	ECM	RESET	CSM	CSM2	Adj R2
4.94	0.51	-0.20*(-2.83)	1.90	S	US	0.39

*shows significance at 5% and ** shows significance at 10%. Abbreviation n.e.s refers to not elsewhere specified. *The critical values for upper and lower bond for 5% and 10% are 2.86 to 4.01 and 2.45 and 3.52 respectively. LM is lagrange multiplier test of residual serial correlation. It is chi square distributed with one degree of freedom. Ramsey RESET test for functional form. It is also chi square distributed with one degree of freedom. Its critical values at 5% (1%) significance is 3.84(6.63). number inside the parenthesis is next to the coefficients are the absolute values of t-ratios.*



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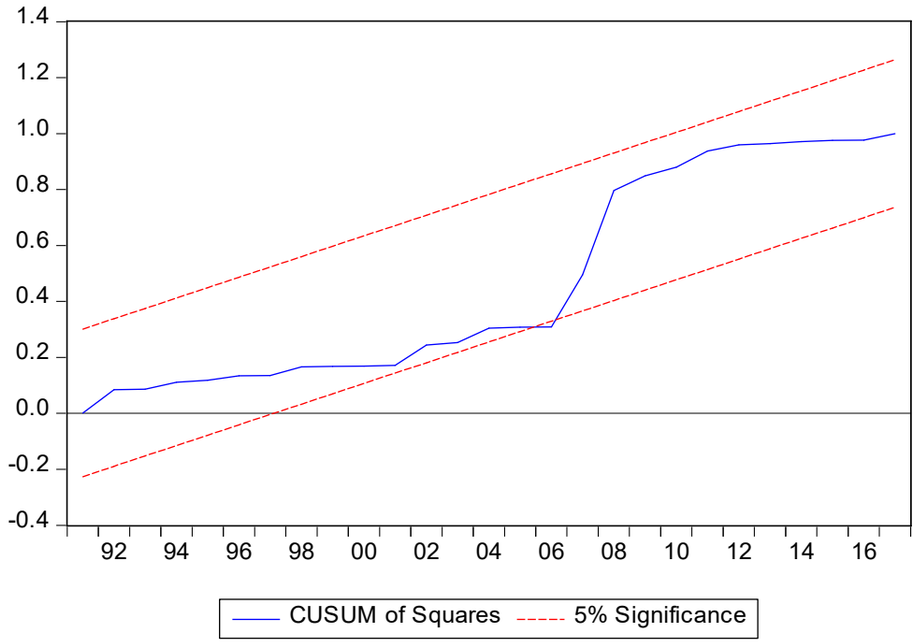

The above graphs show the stability of the model. In CUSUM it will clearly indicate that model is stable, while in the CUSUM of Squares model is weakly unstable. In this study the result shows that there is high relation between the dependent variable and independent variables. The independent variables highly explained the dependent variable.

In this study we have developed a methodology for assessing energy demand response to climate change. Results show that energy demand in Pakistan is sensitive to the climatic and other socio-economic factors. These discoveries propose a need to consolidate the effects of environmental change into local energy framework extension intends to guarantee sufficient stockpile of energy both consistently and for times of pinnacle interest.

5. CONCLUSION AND POLICY RECOMMENDATION

The changing worldwide climate and its likely effects on power utilization in Pakistan. Environmental change could have significant sway on power interest. We have introduced a basic ARDL model including both atmosphere related and financial components which can be utilized basically by utility organizers to survey long haul power designs utilizing long haul assessments of atmosphere boundaries and GDP. The benefit of our methodology is that it is more evident to comprehend the connection between atmosphere related and financial factors and power interest. The study examines the impact of climate change on electricity consumption in Pakistan for the period of 1980-2020. Moreover, this study implies different econometric tests like ARDL, bound test (F-test), ECM test, short run and long run tests, LM test, and Ramsey reset test. Climate variability is receiving much attention recently because it has significant effects on electricity sector and on socio-economic activities of the society especially in developing country such as Pakistan. In view of brief writing with respect to Pakistan it very well may be inferred that power utilization and request assume crucial part in approach plan. Subsequently, the significance of interest side of power area gets essential to be examined. In the wake of investigating significant examinations on power request work at both Pakistan and global level it tends to be inferred that there exists enormous broadening in assessment procedures and results. This examination sorts out the significant determinants of power request which assumes an amazing part in power request induction and opening new ideal models for strategy

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investigation with respect to request the executives. The government will continue to diversify energy supply to meet energy needs in a sustainable and affordable manner. The influence of climate on virtually all human activities implies the need for adaptive strategies to minimize disruption to economic, social, technical and other institutions.

5.2 Policy Recommendations

Public energy approaches, especially sustainable power arrangements, incorporate anticipating abundance limit, an express supportive of helpless measurement, the projection to boost the use of environmentally friendly power sources and the structure of dependable factual information base are should have been made. The expanded utilization of environmentally friendly power ought to be essential for the improvement program, raising political obligation to its advancement. It will require more political will and obligation to accomplish the fruitful executions of these energy plans. Develop an investment attraction strategy to attract foreign and domestic investors and encourage private sector financing. Governments should apply specific policy packages and tax incentives to promote energy efficiency and renewable energy projects. Government should take legislative actions to criminalize the theft of electricity. To be fair, law enforcement must be aligned with the explicit, pro-poor dimension to be included in energy planning. Modernize power plants on a most optimized plan of attack premise to increase supplies and decrease the expense of force age. Follow this with the upgradation and modernization of the current force transmission framework to diminish misfortunes. Endeavors are additionally expected to improve power duty assortment so that assets can be raised for framework activity, support and enhancements of power. There is need to run research projects and improved examinations on biomass applications for power age could be completed at the homegrown level, considering conceivable GHG emanations and agrarian and infrastructural advancement. Creation of biofuel yields ought to be engaged to satisfy the energy need for every single accessible asset. Lobbies for expanding the attention to the populace on energy investment funds and the need for broad utilization of environmentally friendly power sources. Should introduce smart energy bills to make public aware of their electricity consumption.

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