Energy mix and climate change in Pakistan

Syed Murtaza Nadeem
IBA Karachi

1st International Conference, CBER IBA

Title: Energy Mix and Climate Change in Pakistan

Session: Symposium – Lecture Room 2

Date: 4th April 2021 & 11:30 A.M -11:50 A.M

Author: Syed Murtaza Nadeem – IBA, Karachi

https://ir.iba.edu.pk/esdcber/2021/day3/11

Table of Contents

Introduction

Table of Contents: Key Themes in this Research Paper

Chronological timeline of literature on energy and climate change

Carbon emission and the link with energy mix

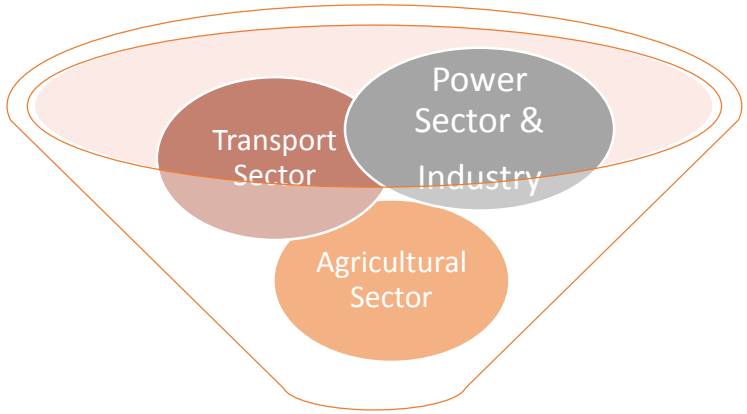
Coal Consumption and carbon dioxide emission

Multiple stakeholders in the energy mix decision making

Long term sustainability of energy mix.

Steps to up-scale renewable energy

Limitations of study, renewable energy and optimal energy mix



Carbon Dioxide Emissions

Climate Change and Global Warming

Energy mix & Climate Crisis

REUTERS

Analysis - Texas blackout: How can electricity grids weather climate shocks?

Bloomberg

U.S. Power Crisis Leaves Millions Cold, Dark as Blackouts ...

The cold blast is just the latest in a chain of severe weather events that have shaken power grids and upended energy markets globally from ...

Financial Times

Fears of Japan blackouts as power prices hit record highs

Japanese electricity prices have soared to all-time highs as a cold snap ... leading experts to predict that the current crisis could add an urgency ...

12-Jan-2021

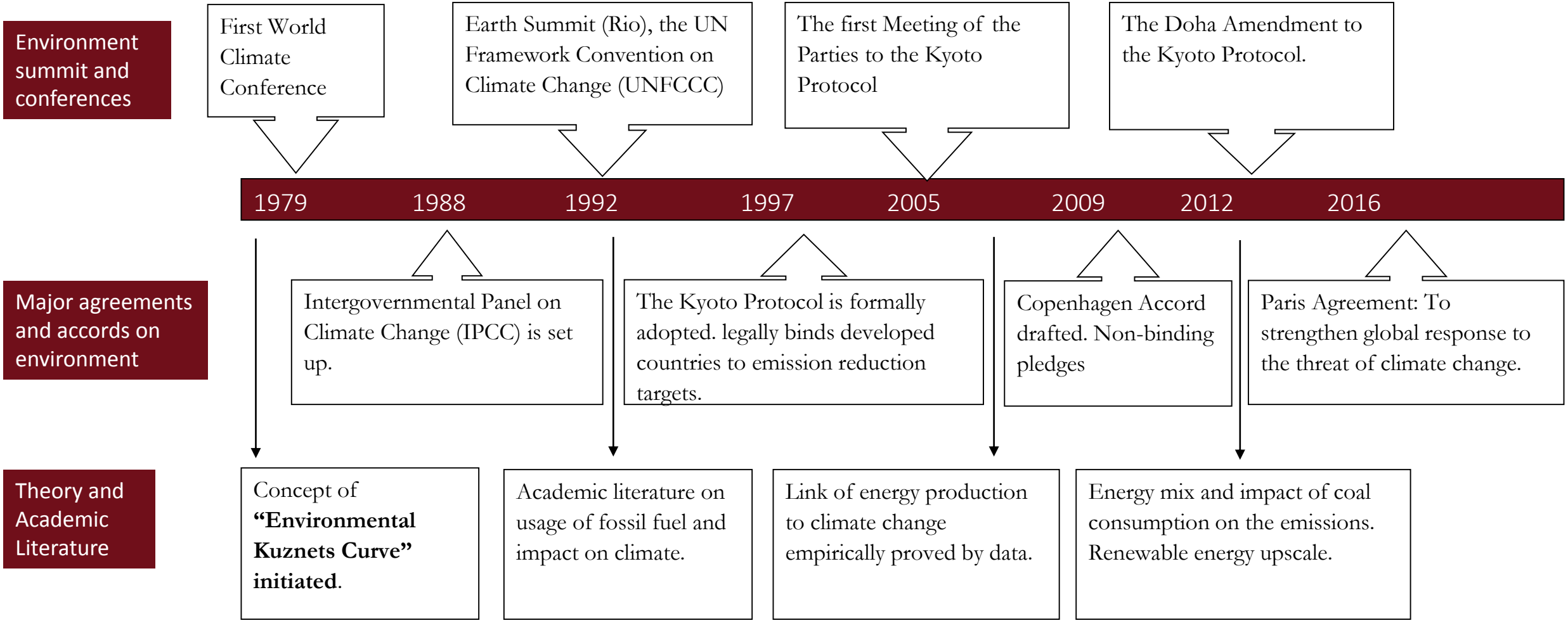
argus

Deep freeze draws coal back into global power mix

https://ir.iba.edu.pk/esdcber/2021/day3/11

Chronology of Literature and Climate Change conferences

This chronology shows timeline of environment theories and major events



Source: https://www.un.org/sustainabledevelopment/climate-negotiations-timeline/

Rational of the study

Increasing greenhouse gas emissions pose risk to environment.

Energy sector is a major cause of carbon dioxide emission.

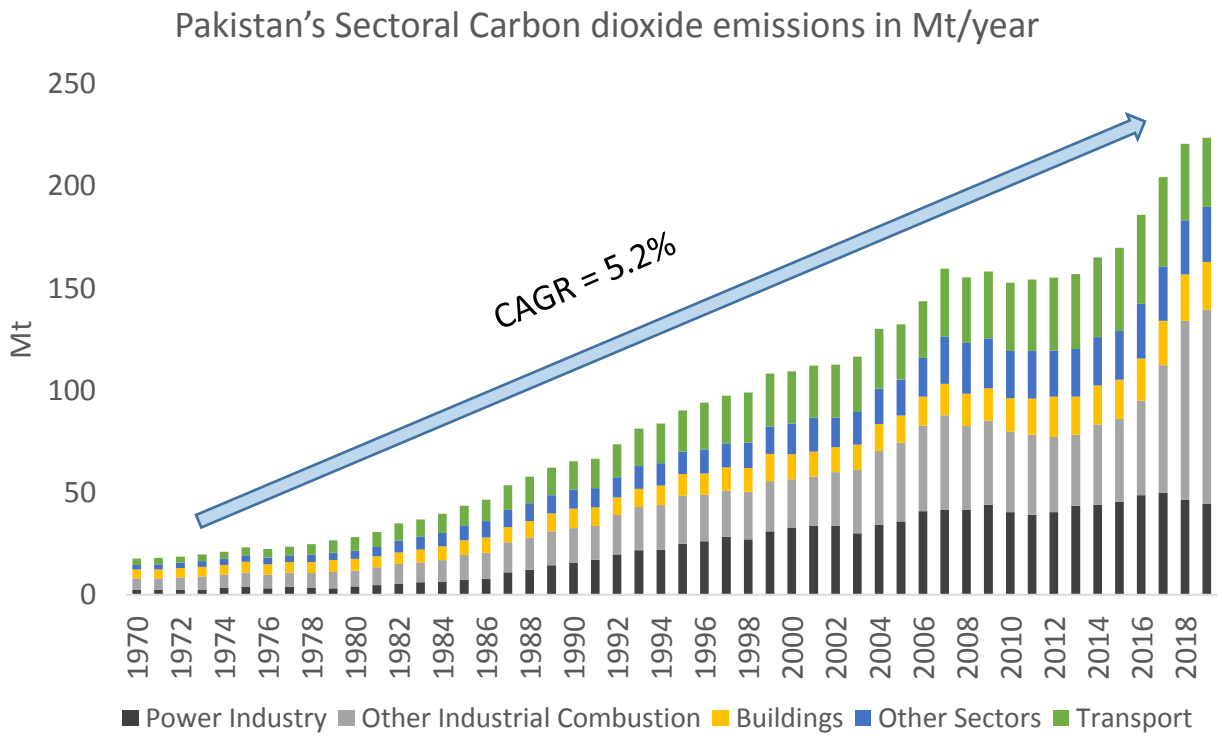
Excess emissions accelerate the global warming issue.

Growing energy demand likely to accelerate global warming.

Energy generation mix plays a vital role in determining emissions.

Risk of energy mix and climate change circularity.

Global crisis of energy mix and implications for Pakistan



Source: EDGAR, Fossil CO2 emissions of all world countries - 2020 Report, EUR 30358 EN

Power Industry Includes power and heat generation plants (public and auto-producers).
Other Industrial Combustion includes combustion for industrial manufacturing and fuel production.

Literature Review

Author Name & Year	Title	Country and/or Region	Methodology & Econometric Tests	Key Findings
V.G.R. Chandran Govindaraju, Chor Foon Tang 2012-2013	**The dynamic links between CO2 emissions, economic growth and coal consumption in China and India**	China and India	Method of cointegration & Granger causality test is used to evaluate link of CO2 emissions, economic growth and coal consumption in China and India.	Results indicate variables are cointegrated in the case of China but not India. Granger causality test for China reveal a strong evidence of unidirectional causality running from economic growth to CO2 emissions.
Suhail Zaki, Farooqui 2013	**Prospects of renewables penetration in the energy mix of Pakistan**	Pakistan	A survey of the availability of various renewable energy sources, and their penetration prospects in energy mix.	It is estimated that Pakistan has the feasible potential of 30 GW of installed power capacity from hydel and 50GW of installed capacity from wind by 2030.
Helen Cabalu, Paul Koshy, Erwin Corong, U-Primo E. Rodriguez, Benjamin A. Endriga. 2015	**Modelling the impact of energy policies on the Philippine economy: Carbon tax, energy efficiency, and changes in the energy mix.**	Philippine	This paper develops a computable general equilibrium (CGE) model of the Philippine economy to analyze the effects of such climate change policy options in the period to 2020.	The modelling results indicate that given the current level of development in the Philippine electricity generation and transport sectors, even relatively modest measures have marked impacts one emissions with marginal economic impacts.
Syed Anees Haider Zaidi & Danish, Fujun Hou & Faisal Mehmood Mirza 2018	**The role of renewable and non-renewable energy consumption in CO2 emissions: a disaggregate analysis of Pakistan**	Pakistan	This paper develops empirical evidence from auto-regressive distributive lag (ARDL) model of data from 1970 to 2016.	Renewable energy consumption has an insignificant impact on CO2 emission in Pakistan while natural gas and coal are the main contributors to the level of pollution in Pakistan.

Literature Review

Author Name & Year	Title	Country and/or Region	Methodology & Econometric Tests	Key Findings
Boqiang Lin, Muhammad Yousaf Raza 2019	**Analysis of energy related CO2 emissions in Pakistan**	Pakistan	Logarithmic Mean Divisia Index technique using data from (1978 – 2017) and scenario analysis.	Shift in population, activity effects and gross domestic product are important factors causing increase in CO2 emissions.
Daniel Balsalobre-Lorente, Muhammad Shahbaz, David Roubaud, Sahbi Farhani, 2018	**How economic growth, renewable electricity and natural resources contribute to CO2 emissions?**	Europe (EU-5) (Germany, France, Italy, Spain, and the United Kingdom)	Carbon emission function to investigate the environmental Kuznets curve for 1985–2016 period.	The empirical results confirm the existence of an N-shaped relationship between economic growth and CO2 emissions in the EU-5 countries.
Muhammad Zeshan Akber, Muhammad Jamaluddin Thaheem, Husnain Arshad 2017	**Life cycle sustainability assessment of electricity generation in Pakistan: Policy regime for a sustainable energy mix**	Pakistan	In total, 20 sustainability indicators have been assessed covering life cycle of seven electricity generation sources, currently in use.	Hydropower is found as the most sustainable option having lowest environmental and economic impacts. While due to worst economic and social impacts, oil is found to be the least sustainable option for the country.
Selahattin Murat Sirin, Irem Sevindik 2021	**An analysis of Turkey's solar PV auction scheme: What can Turkey learn from Brazil and South Africa?**	Turkey	LCOE analysis to demonstrate that the project is vulnerable to macroeconomic shocks and financial risks.	Model results show that the capacity factor is the most prominent factor in costs, and 10% change in the capacity factor affects the LCOE about the same rate.

Analysis & Proposed Model

Analysis of INDC Forecast

Inventory of GHG Emissions (in MT CO2-equivalent) and projected emissions for 2030						
Sectors	1994	2008	2012	2015	Forecast - 2030	CAGR 2015 - 2030
Energy	85.8	168.47	171.44	185.97	898	11.1%
Agriculture	71.63	125.97	162.86	174.56	457	6.6%
Industrial Processes	13.29	18.54	19.59	21.85	130	12.6%
Land Use Change & Forestry	6.52	9.29	9.67	10.39	29	7.1%
Waste	4.45	7.24	10.55	12.29	89	14.1%
Total	182	330	374	405	1603	9.6%

Source: Pakistan's Intended Nationally Determined Contribution (PAK-INDC) Document

- As part of an international policy climate regime, governments are required to submit Intended Nationally Determined Contributions to achieve stabilization of GHG
- Pakistan's submission shows alarming levels of emissions increase from energy sector.
- This is primarily due to capacity additions in non-renewable projects specifically coal power projects.

ARIMA Model For Carbon dioxide forecasting

The ARIMA model is denoted by ARIMA (p,d,q) where "p" represents order of the auto regressive process, "d" is the order of the data stationary and "q" is the order of the moving average process.

ARIMA model can be written as:

$$\Delta^d y_t = \delta + \theta_1 \Delta^d y_{t-1} + \theta_2 \Delta^d y_{t-2} + \cdots + \theta_p \Delta^d y_{t-p} + e_{t-1}\, \alpha\, e_{t-1} - \alpha_2 e_{t-2}\, \alpha_q e_{t-2}$$

where, Δ^d denotes differencing of order d, i.e., $\Delta y_t = y_t - y_{t-1}$, 1, , $\Delta^2 y_t = \Delta y_t - \Delta y_{t-1}$, and so forth, and $y_{t-1}, \ldots, y_{t-p}$, are past observations (lags), and $\cdots$ $\delta, \theta_1, \ldots, \theta_p$ are parameters (constant and coefficient)

y_t $represents$ $\ln(carbon\ dioxide\ emissions\ in\ Pakistan\ at\ time\ t)$

The steps which are followed in order to define an ARIMA model as stated by Box & Jenkins:

a) Identifying a model;
b) Estimating the parameters of the model;
c) Diagnostic checking.

Data

Carbon dioxide emission

- Type: Time Series Data
- Unit: Mt of Co2/ year
- Periodicity: Annual
- Series – Years : 1991 – 2019
- Source: EDGAR, Fossil CO2 emissions of all world countries - 2020 Report

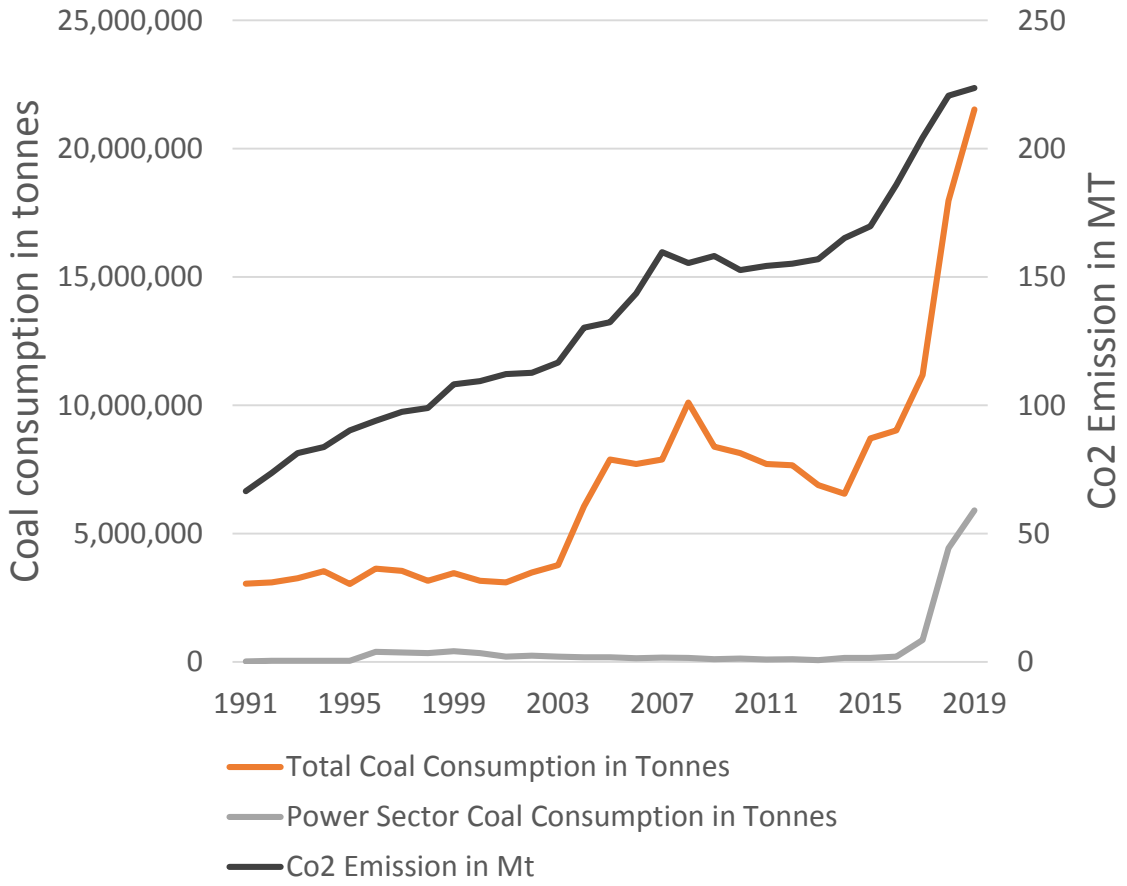
Coal Consumption

- Type: Time Series Data
- Unit: Tonnes
- Periodicity: Annual
- Series – Years : 1991 – 2019
- Source: Energy Yearbook Pakistan (Various Editions)

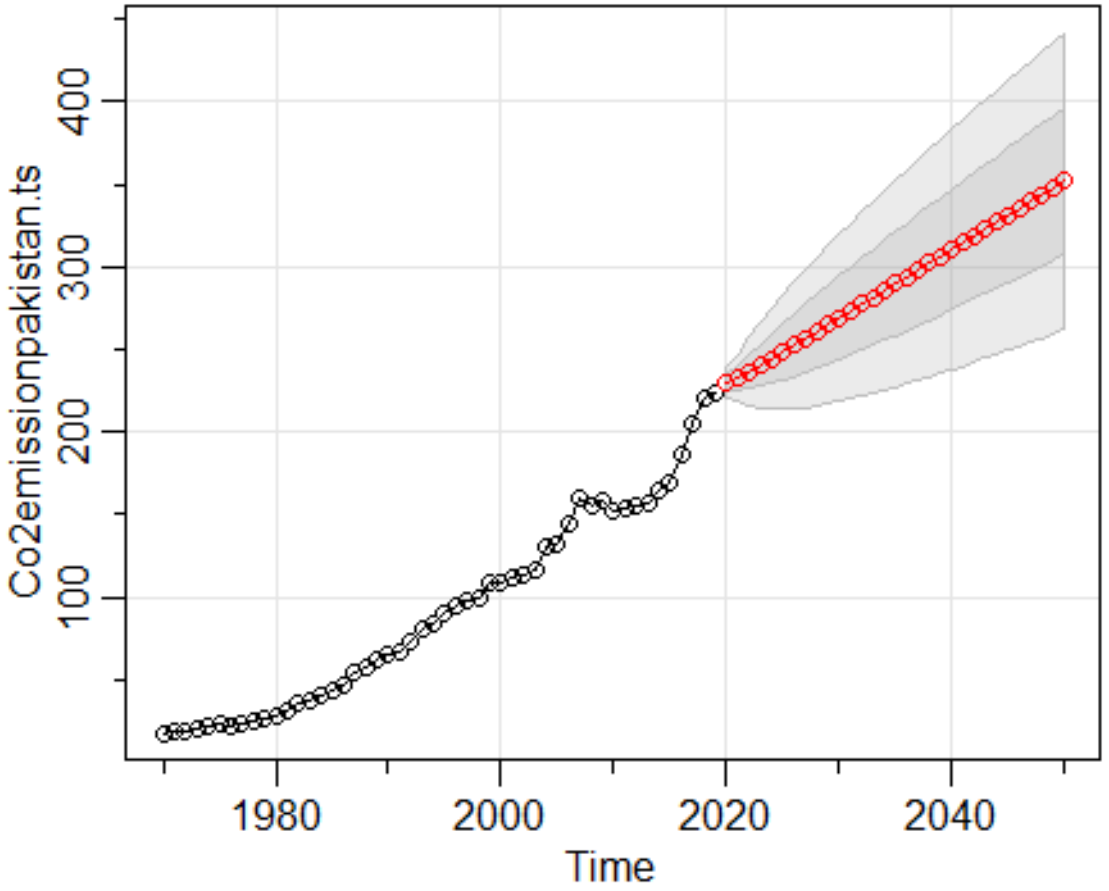
Summary Statistic	Co2 Emission (Mt)	Total Coal Consumption (tonnes)	Coal Consumption in power sector (tonnes)
Mean	135	6,786,380	544,554
Standard Deviation	42.70	4,421,858.34	1,306,545.19
Variance	1,823	19,552,831,210,221	1,707,060,344,141
Coefficient of Variation=sd/x	0.32	0.65	2.40
Min	67	3,042,839	24,603
Maximum	224	21,527,068	5,901,536
Range	157	18,484,229	5,876,933
Quartile 1 - 25th percentile	99	3,461,444	104,604
Quartile 2 - 50th percentile	132	6,557,452	164,397
Quartile 3 - 75th percentile	158	8,138,503	346,549
Quartile 4 - Max Value	224	21,527,068	5,901,536
Interquartile Range = Q3-Q1	59	4,677,059	241,945

Data Visualization

Pakistan Co2 emission and coal consumption



Co2 Emission forecast using R



https://ir.iba.edu.pk/esdcber/2021/day3/11

Model Selection Criteria

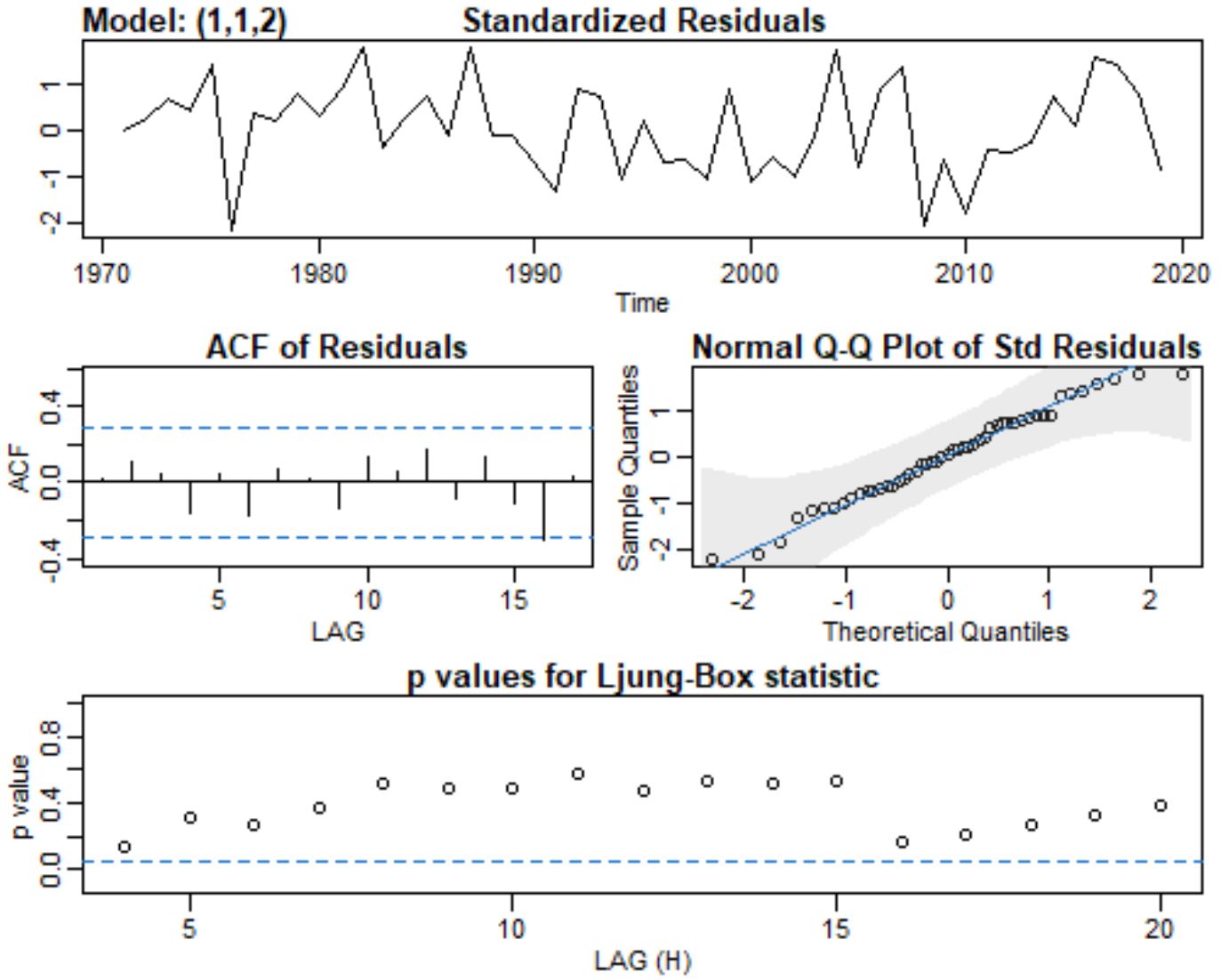
- Checked model fitting by using various combinations as well.

- Checked for the lowest AIC, and BIC for the best parameters.

- R Code for the model for checking fitting of Seasonal ARIMA model
  sarima(lnco2emission.ts, 1, 1, 2)

- R code for the plot of ARIMA forecast on the next page
  sarima.for(Co2emissionpakistan.ts, n.ahead = 31, 1, 1, 2)

ARIMA Model



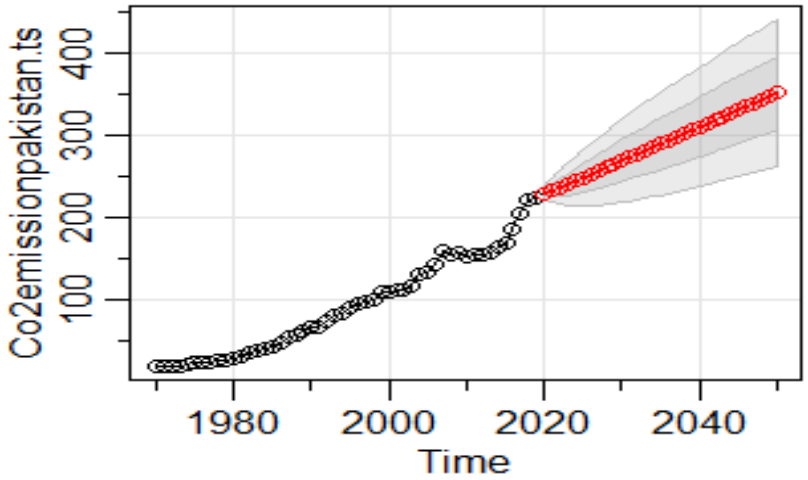
Source: Data: EDGAR Co2 emissions JCR Report.
Chart: R – R studio for calculations and forecast using ARIMA

Conclusion and Findings

INDC forecasts depict overestimation but increasing coal consumption trajectory can act as catalyst.

- As per academic research emissions are linked to energy production and GDP.
- A CAGR of 9.6% depicts overestimation in emissions, as past statistics show gradual increase in emissions as a percentage of GDP.
- While conducting cointegration tests between coal consumption and carbon dioxide emission in Pakistan, existence of long run relationship can be seen.
- Causality test reveal uni-directional causality from coal consumption towards carbon emission.
- Although the causality of coal consumption in power sector and carbon dioxide emission does not show significant causality at this stage but the incoming coal power projects under CPEC are expected to hike the coal consumption in power sector.
- In the above scenario, power sector coal consumption is expected to cause surge in carbon dioxide emissions in the future years.

Forecasting carbon dioxide emission of Pakistan in 2050 using ARIMA



- Based on he forecast results the carbon dioxide emissions are expected to reach ~350 Mt which is a drastic increase of more than 100 Mt.
- Therefore, the government should rethink the policy about how to reduce the emissions to prevent further climate change disasters.
- The forecast result also shows the grey boundary around red forecast line. It basically indicates the standard error from the forecast result. Emission forecasting is difficult so it has greater intervals.

Conclusion and Discussion

Emissions & INDC forecast indicate upcoming energy policy and environmental issues

Targets	• The government should set targets for renewable energy to develop a diversified energy mix.
PPA	• Just like power purchase agreements are decided to be renegotiated with the IPPS, similarly the government should consider the same with CPEC based coal power projects.
Energy Dynamics	• While NEPRA may argue that these power projects were approved at a time when there was power shortage, the current situation has changed, and the country has an energy surplus
Steps	• Various steps can be taken to upscale the renewable energy in Pakistan which we discuss in next few slides
Downsides	• Renewable energy also has limitations which are considerable in case of Pakistan
Stakeholders	• Multiple stakeholders such as federal government, provincial government, lobbies, public, pressure groups make decision making even more difficult in energy business

https://ir.iba.edu.pk/esdcber/2021/day3/11

Conclusion & Recommendations

Energy Policy

- Worsening indicators depict that government should reconsider CPEC coal power projects and at least renegotiate PPA's.
- Government should focus on a diversified energy mix and incorporate climate factors in energy policy.

Environment Policy

- While governments discuss climate change, they fail to show any understanding of energy and environment link.
- Environmental policy should consider energy mix and production as well.

Findings & Implications

Optimal Energy Mix

- Optimal energy mix is the diversified energy mix that meets the energy needs of the country with a limited surplus and is both economically & environmentally sustainable for the current & future generations.

Policy Implications

- Government should aim to target optimal energy mix by decreasing coal usage in power sector and increasing renewable energy for diversification in energy mix.

https://ir.iba.edu.pk/esdcber/2021/day3/11

Drawback & Limitations of the study

Research Limitations

Limitations of Study

Limitations of ARIMA

- ARIMA as well because it forecasts linearly and assumes that there is no change in government policy. It only uses past data of emissions to forecast.

Limitations of Causality

- Granger causality is not a true causality test. It may produce misleading results when the true relationship involves three or more variables.

Data Limitations

- Carbon dioxide emissions can be attributed to concentration of industries and coal power plants in certain cities and also includes spillover effects of pollution from neighboring countries especially India and China.
- Specific formulae is used for Co2 emissions which varies.
- Pakistan energy yearbook mentions that sectoral data consumption of coal is mostly not available, except for power sector and has therefore been estimated to calculate the total coal consumption in Pakistan.

Limitations of Renewable Energy

Variable Output Nature

- Renewable energy generation is variable in nature due to weather and climate.

Storage Cost and Technology

- With the improvement in technology in solar panel photo-voltaic (PV) is now cheaper however battery storage technology is still expensive.

Peaking Season Issues

- Limited benefit in peaking season in comparison to fossil fuels

Argument of Unemployment

- Renewable energy is not labour intensive, therefore transition may lead to unemployment.

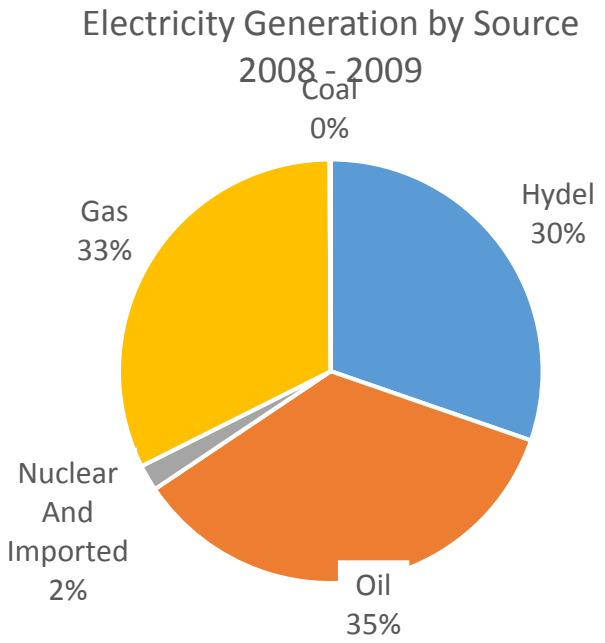
Therefore, a diversified sustainable energy mix is optimal.

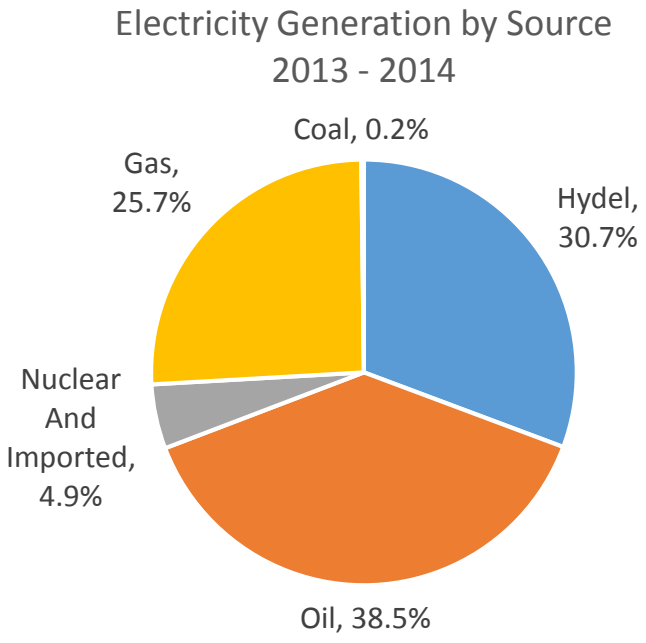
Thank You

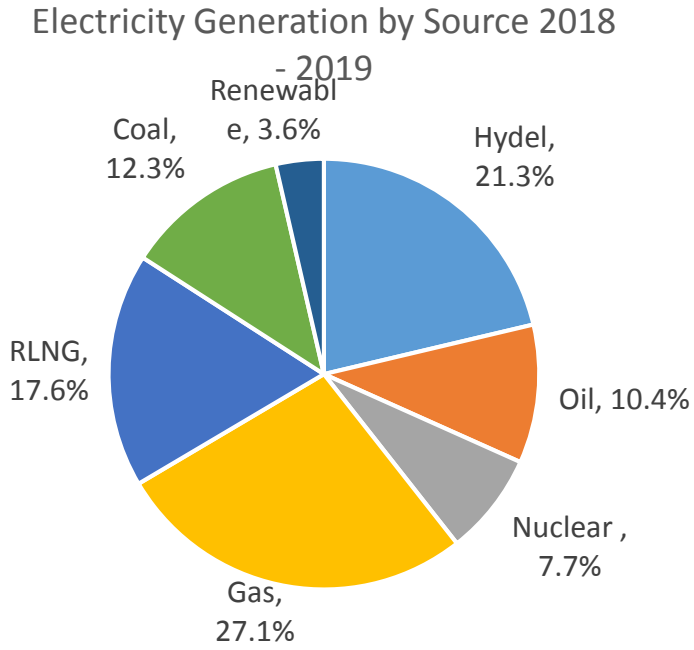
https://ir.iba.edu.pk/esdcber/2021/day3/11

Appendix

These charts show the surge in coal usage in electricity generation mix of Pakistan



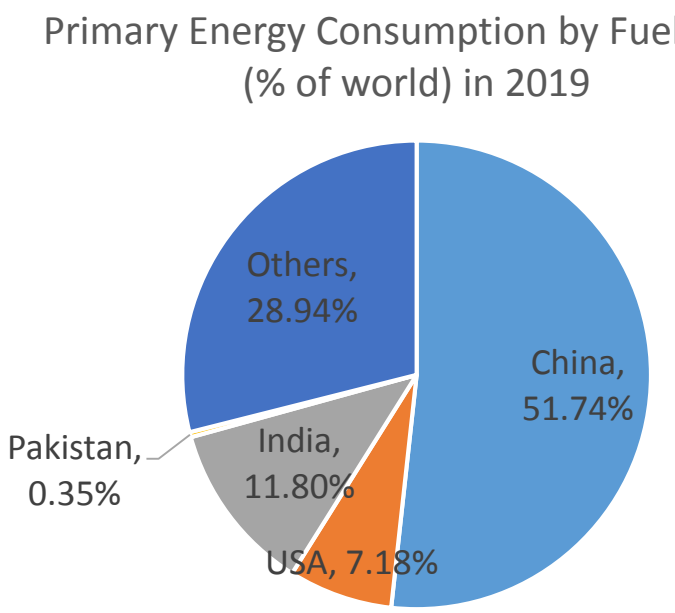


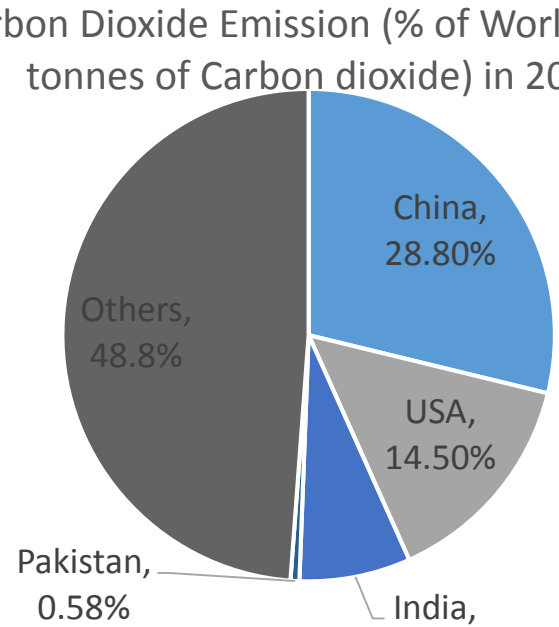


Source : Pakistan Energy Yearbook – (2009, 2014 and 2019 edition)

- The share of oil and gas has dominated Pakistan's energy generation mix over the past decade.
- Share of coal has recently increased In 2019 to 12.3% from 0.2% in 2013. As per NEPRA, Coal's share in power generation surged to 25% in October 2019.

Major countries contributing to Co2 emissions consume more coal globally





- China, India and USA are major consumers of coal, contributing to about half of the worlds carbon dioxide emissions.
- In its recent report IMF, (World Economic Outlook Oct 2020) mentions that many countries are taking steps to reduce their dependence on fossil fuels, especially coal, as they seek to pursue a more sustainable future.
- Due to high carbon intensity, coal accounts for just under half of global CO2 emissions and nearly three-quarters of all power sector CO2 emissions. In the absence of pollution mitigation systems, it contributes to local air pollution, with potentially severe damaging effects on human health (Smith et al., 2004).

https://ir.iba.edu.pk/esdcber/2021/day3/11

Proposed Model

Granger Causality Model

$$Y^t = \sum_{k=1}^{p} \alpha_k X_{t-k} + \sum_{l=1}^{q} \beta_k Y_{t-k} + \epsilon_t$$

$$X^t = \sum_{i=1}^{m} \alpha_i X_{t-i} + \sum_{j=1}^{n} \beta_j X_{t-j} + \varepsilon_t$$

Y^t= log carbon dioxide emission in Pakistan
X^t= log coal consumption in Pakistan
within which $\epsilon_t \sim N\ (0, \delta_\epsilon^t)$ and $\varepsilon_t \sim N\ (0, \delta_\varepsilon^t)$

Null Hypothesis Ho: $\beta_1 = \beta_2 = \ldots = \beta_j = 0$
Alternate Hypothesis Ha: At least one parameter of $\beta_j \neq 0$

If there are at least a parameter value of βj not zero, which indicates that the equation of null hypothesis does not hold, it proves that $X_t\ (Coal\ Consumtion)$ does strictly Granger cause $Y_t\ (Carbon\ dioxide\ emission)$.

ARIMA Model For Carbon dioxide forecasting

The ARIMA model is denoted by ARIMA (p,d,q) where "p" represents order of the auto regressive process, "d" is the order of the data stationary and "q" is the order of the moving average process.

ARIMA model can be written as:

$$\Delta^d y_t = \delta + \theta_1 \Delta^d y_{t-1} + \theta_2 \Delta^d y_{t-2} + \cdots + \theta_p \Delta^d y_{t-p} + e_{t-1}\, \alpha\, e_{t-1} - \alpha_2 e_{t-2}\, \alpha_q e_{t-2}$$

where, Δ^d denotes differencing of order d, i.e., $\Delta y_t = y_t - y_{t-1}$, 1, , $\Delta^2 y_t = \Delta y_t - \Delta y_{t-1}$, and so forth, and $y_{t-1}, \ldots, y_{t-p}$, are past observations (lags), and $\cdots$ $\delta, \theta_1, \ldots, \theta_p$ are parameters (constant and coefficient)
$y_t\ represents \ln(carbon\ dioxide\ emissions\ in\ Pakistan\ at\ time\ t)$

The steps which are followed in order to define an ARIMA model as stated by Box & Jenkins:
a) Identifying a model;
b) Estimating the parameters of the model;
c) Diagnostic checking.