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Climate Management and Paris Agreement: A Predictive Evaluation

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Abstract

The present endeavour attempts to assess the impact of increased carbon emissions on the global mean annual temperature by employing an autoregressive distributed lag model (ARDL) on time series data for 1970-2020. The study aims to predict the expected increase in global mean temperature until 2100 by considering the mean annual temperature as the dependent variable, while taking carbon emissions as the independent variable. Additionally, control variables such as electricity from coal sources, energy imports, fossil fuel energy consumption, and water productivity are considered. The findings show that the expected increase in global mean temperature will be 4.1°C, which is higher than the temperature increase expected by the turn of the century. The conclusions reveal that the expected annual mean temperature increase is likely to surpass the 1.5°C and 2°C limits set in the Paris Agreement by 2029 and 2043, respectively. The study recommends a straight cut in global annual carbon emissions by 1.02% from the year 2029 and 0.94% from the year 2043 so as to meet the Paris Agreement targets and to make the planet Earth sustainable. Therefore, the study calls for technological solutions, strict compliance with the respective NDCs, technology transfer to the South, and quickly shifting to non-fossil fuels cumulatively to help the planet towards sustainability.

Keywords: ARDL, Climate Change, Carbon dioxide, Global Warming, Paris Agreement, Pledges

JEL Classifications: C13, H7, Q54

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1. Introduction

Global warming refers to the long-term warming of the planet's overall temperature due to human and natural processes (Mella, 2022). The rapid population increase, industrialisation, and burning of fossil fuels accelerated the emission of Greenhouse gases (GHGs). The GHGs, such as carbon dioxide, methane, nitrous oxide, and fluorinated gases, prevent the heat from leaving the atmosphere, causing the average global temperature to rise over time, known as global warming (Mann, 2023). Global warming has increased global mean surface temperatures by 1.1 °C (2.0 °F) since the industrial revolution (World Meteorological Organization [WMO], 2022; Intergovernmental Panel on Climate Change [IPCC], 2023). Global warming affects all parts of Earth's climate system (WMO, 2019). The climate scientists forecast that the mean global temperature will be 2°C to 4°C higher than they were before 1750 (National Oceanic and Atmospheric Administration (NOAA), 2021).

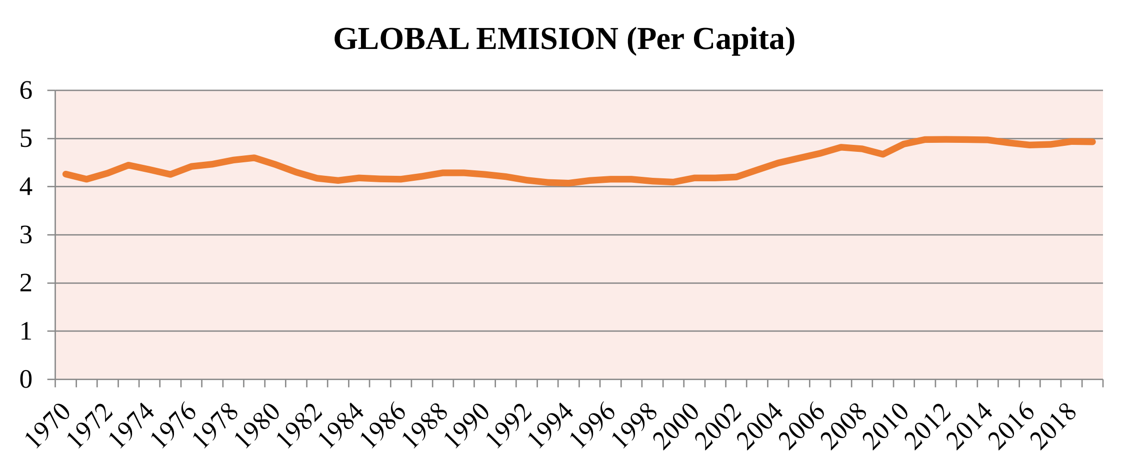
The mean global GHG emission increased at 3 per cent per year, especially in the last three decades of the 20th century. This increase was mainly driven by the 6 per cent average annual growth in CO2-e emissions since 1970, i.e., from 24.5 gigatons in CO2 equivalent (GtCO2-e) in 1970 to 37.2 GtCO2-e in 2002, excluding land-use change (Olivier & Peters, 2020). Different regions of the globe experience the differentiated impacts of climate change (National Aeronautics and Space Administration (NASA), 2020). In 2021, the National Canters for Environmental Information released the Global Climate Report for the year 2021, which shows that the global annual temperature has increased at an average rate of 0.8°C per decade since 1880 and has more than doubled (0.18°C) since 1981. A similar pattern appears in Asia and Africa. Europe experienced the highest increase in annual temperature, three times more than the rate since 1981, while South America and Oceania experienced less than twice during the same period (NASA, 2020). The Arctic is warming faster than most other regions (Lindsey & Dahlman, 2022).

Globally, the per capita emissions of CO2-e have been increasing very fast since the 1990s (Figure 1). Figure 2 shows the lion's share of global greenhouse gas (GHGs) emissions (excluding those from land-use change), which was highest for fossil CO2 (73 per cent) and methane (19 per cent), leaving the other GHG shares of 5 per cent in N2O and 3 per cent in F-gases (Olivier & Peters, 2020). Further, the contribution of electricity and heat production in total GHGs emissions is 25 per cent, closely followed by agriculture, forestry, and other land use (24 per cent), industry (21 per cent), transportation (14 per cent), other energy sources (10 per cent) and the rest 6 per cent contributed by buildings (IPCC, 2014).

Oxfam International (2020) revealed considerable inequalities in carbon emissions, as the wealthiest 10 per cent of people are responsible for 52 per cent of the cumulative carbon emissions, while the poorest 50 per cent account for just 7 per cent. Similarly, the research by Gore (2020) pointed out that the wealthiest 10 per cent alone would fully deplete the global carbon budget by nearly a third in the next two and a half a decade alone, even if everyone else's emissions dropped to zero tomorrow. Hence, different sections/sectors of society/economy share the responsibility for global emissions differently.

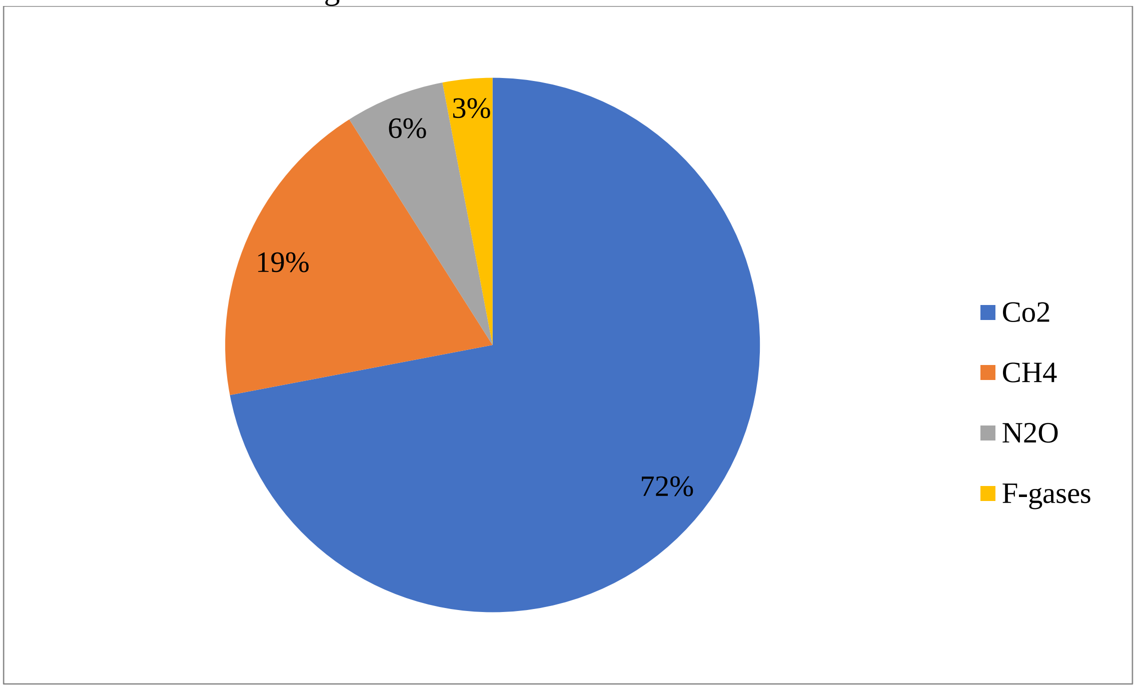
Research indicates a hidden disaster for agriculture (Panghal & Mor, 2020), declining cropland revenue (Mor, 2017a), and more adversity for small farms (Mor & Jindal, 2012; Mor, 2017b) confirmed a "U" shape relationship for economies in transition (EIT), thereby suggesting that the growth of per capita cannot improve the environmental quality (Mor, 2014). Hence, countries can decide on the present value of higher future growth and a better-quality environment in the future at the cost of the current rate of degradation of environmental resources (Mor & Singh, 2019).

Figure 1: Global Trends of emission (Per capita)



Source: Compiled from Olivier & Peters (2020).

Figure 2: Share of GHGs in total emission



Note: The GHGs estimates exclude land-use changes.
Source: Trends in Global Emission (Olivier & Peters, 2020).

The Kyoto Protocol was ratified in 1997 with the aim of reducing greenhouse gas emissions from participating industrialized countries (Huang et al., 2008). Although its ratification laid the groundwork for future climate protection initiatives, it ultimately fell short in achieving significant reductions in emissions (Böhringer, 2003). Research shows a mixed impact of the Kyoto Protocol in achieving its objectives in the commitment periods. Grunewald & Martinez-Zarzoso (2016) revealed that Kyoto Protocol commitments have a measurable reducing effect on CO2-e emissions, indicating that a treaty often deemed a 'failure' may be producing some non-negligible effects for those who signed it, while Rosen (2015) regarded it as a fundamentally flawed agreement that set back solutions on climate change by two decades. All 36 Annex-1 parties met their emission reduction targets in the CP-1, owing to the financial crisis of 2007-08 and using various mechanisms under the Protocol; however, the global emissions up by 32 per cent in 2010 compared to 1990 (Shishlov et al., 2016).

The Paris Agreement offers more likelihood of stable and long-lasting international cooperation owing to its inbuilt national mechanism and a 'ratchet mechanism' (Falkner, 2016), strengthening liberal environmentalism even in the post-agreement landscape (Jernnäs & Linnér, 2019). However, the Earth's temperature is still set to increase by 3-4°C, almost double the agreement of limiting it to 1.5-2.0°C even if all national pledges are fully realized (Young, 2016), and it is tough to infer anything about its effectiveness in decarbonising the Earth at this juncture (Falkner, 2016). Moreover, the global annual temperature has increased at an average rate of 0.08°C per decade since 1880 and over twice that rate (+0.18°C) since 1981 (NASA, 2020).

In addition to CO2-e emission, this study also considered several other variables to examine their impact on global mean annual temperature. These variables included electricity generated from coal sources, energy imports as a percentage of total energy use, fossil fuel energy consumption as a percentage of total energy, and water productivity (measured as the total 2015 US dollar GDP per cubic meter of freshwater withdrawal).

It is crucial to acknowledge that our current electricity generation heavily relies on fossil fuels, which emit carbon dioxide and contribute to climate change. Fossil fuels are burned to power turbines or generators that use heat to turn and create electricity. Despite the slowdown in the investment in coal-induced electricity, coal use is unlikely to decline substantially in the medium term. Burning fossil fuels for electricity contributes to greenhouse gas emissions and leads to global warming and climate change. Coal remains the primary fuel source for electricity generation globally, and coal combustion still accounts for 40 per cent of global CO2 emissions from energy use (Jakob et al., 2020). Recent studies reveal that more than 60 per cent of global electricity generation relies on fossil fuel sources that emit carbon dioxide (Hong & Slatick, 1994; Gasparotto & Da Boit Martinello, 2021; IPCC, 2023). Voumik et al. (2023) established that coal-fired power plants have a substantial positive impact and a more significant impact on CO2 emissions regardless of the technology used to generate coal and gas power.

CO2 emissions from energy use significantly contribute to global warming and account for some 75 per cent of all artificial greenhouse gas emissions in the European Union (EU). CO2 emissions from fossil fuels originate in the country where the fuels are burned for electricity generation, transport, steel production, etc., which consequently impacts imports and exports of energy products (Eurostat, 2022). Pan et al. (2024) examined the impact of energy imports and natural resource income on environmental degradation in the Asia-Pacific Economic Cooperation (APEC) countries from 1990 to 2020. They elucidated that importing energy from countries specializing in renewable energy can help reduce reliance on fossil fuels. The study further reveals that renewable energy consumption mitigates CO2 emissions, while real GDP per capita has a positive effect. Research by Li et al. (2023) confirms that the Environmental Kuznets curve is valid in energy-importing emerging economies. Dulal et al. (2021) confirmed that a 1 per cent increase in oil, coal, and gas-based energy generation capacity increases carbon emissions by 1.25 per cent, 1.48 per cent and 0.93 per cent, respectively. There was little difference in the percentages of carbon emissions when coal was imported. In a similar study, Martins et al. (2021), using an error correction model, showed that 47.39 per cent of a shock in the carbon dioxide emissions variable is resolved in one year. After two years, carbon dioxide emissions return to long-term equilibrium.

Water is a critical resource for all human, agricultural and manufacturing activities, and reductions in water use through water efficiency is one method for mitigating risk. Water scarcity is a global risk that could be mitigated by using water more efficiently, increasing water's productivity. However, the effects of water productivity on water stress have yet to be empirically tested or validated across countries. The study by Doeffinger & Hall (2020) exhibited that water stress is initially likely to increase in the development path. Danish (2020) employed the auto-regressive distributive lag model (ARDL) to estimate the long-term and short-term impact on carbon emissions. He reported a two-way causality between water productivity, carbon emissions, energy consumption, and water productivity. In the same tune, Karki & Rao (2023) showed significant opportunities for water and energy use reduction revenue generation. The agriculture and manufacturing sectors have the most significant indirect water footprint due to their reliance on water-intensive inputs. However, these sectors also have the most incredible capacity to reduce water consumption throughout their supply chains (Marston et al., 2020).

The paper aims to assess the global mean annual temperature increase till 2100 in light of the limits set by the Paris Agreement. The article further forecasts the emission of CO2 with the increase in global mean annual temperature change in three scenarios, i.e., Scenario I (1970-2020), II (1990-2020), and III (2010-2020). For this research, we used time series data on total global emission (CO2-e) and mean annual global temperature (°C) for 1970-2020. The forecasting for global mean average temperature is made using an autoregressive distributed lag model (ARDL). The research is expected to provide a reliable empirical forecast pertaining to the CO2-e emission as well as global mean annual temperature till the turn of the century.

The paper unfolds as follows: Section 2 highlights the mechanism of the Paris Agreement, while Section 3 deals with the methodology employed in the study. Section 4 pertains to the results and discussion, while Section 5 concludes the paper.

2. Mechanism of the Paris Agreement

The present study focuses on the Paris Agreement as it encompasses a framework for making voluntary pledges and a marked shift towards voluntary commitments for all in emission reduction, which can be compared and reviewed internationally. Further, it aligns most of the nations of the world. The Paris Agreement, with the new logic of ‘pledge and review,’ may make a big difference in promoting international mobilization and generating political momentum in pursuit of more substantial global climate policies (Falkner, 2016). The Paris Agreement was adopted at the annual gathering of parties to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 and entered into force less than a year later (Wirth, 2017). It was adopted by 196 Parties at Conference of Parties (COP) 21 in Paris on December 12, 2015, and entered into force on November 4, 2016 (UNFCCC, 2015) and aims to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. Parties aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate-neutral world by mid-century.

The Paris Agreement is a landmark in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects (UNFCCC, 2015). The Paris Agreement under UNFCCC requires economic and social transformation based on the best available science and technology (UNFCCC, 2015). The Paris Agreement works on a 5-year cycle of increasingly ambitious climate action by countries. By 2020, countries submit their plans for climate action known as nationally determined contributions (NDCs).

- NDCs: In their NDCs, countries communicate actions to reduce their greenhouse gas emissions to reach the Paris Agreement's goals. Countries also communicate their actions in the NDCs; they will build resilience to adapt to the impacts of rising temperatures.
- Long-Term Strategies: The Paris Agreement invites countries to formulate and submit their long-term low greenhouse gas emission development strategies (LT-LEDS) with a view to better frame the efforts towards the long-term goal by 2020.
- LT-LEDS provide the long-term horizon to the NDCs. Unlike NDCs, they are not mandatory. Nevertheless, they place the NDCs in the context of countries' long-term planning and development priorities, providing a vision and direction for future development.
- With the Paris Agreement, countries established an enhanced transparency framework (ETF). Under ETF, starting in 2024, countries will report transparently on actions taken and progress in climate change mitigation, adaptation measures, and support provided or received. It also provides international procedures for the review of the submitted reports.

The Paris Agreement is described as a breakthrough in international climate policy by accepting the predominance of domestic climate change (Falkner, 2016), representing a marked shift towards voluntary commitments for all in the spheres of emission reduction instead of earlier legally binding emission reduction targets based on standard metrics for developed countries (Janetschek et al., 2020), and sets forth a new international legal regime aimed at strengthening the global response to climate change (Horowitz, 2016). The success of the Paris Agreement depends upon the transparency in the determination of INDCs and NDCs by respective parties (Mor & Ghimire, 2022).

3. Methodology

The study is designed to predict climate change based on the promises made by member nations in the Paris Agreement. To do so, we applied Autoregressive Distributed Lag (ARDL) cointegration, and ARDL bound testing approach for cointegration has been developed (Pesaran & Smith, 1998; Pesaran et al., 2001). This approach is suitable for time series variables exhibiting a mixed relationship between I (0) and I (1) series in a series. The ARDL bound testing approach tests the long-run equilibrium relationship between mean annual temperature °C (MAT) as the dependent variable and explanatory variables such as carbon emission (EMS), electricity from coal sources (ECY), energy imports (ENI), fossil fuel energy consumption (FEC) and water productivity (WPY). The main advantage of the ARDL model, given the power and testing of the long-run relationship, is that it can be applied irrespective of the order of integration (and in small samples). At the same time, other cointegration techniques require all variables to have an equal degree of integration (and large samples).

In the ARDL model outlined, we first test the null of no cointegration (i.e., H0: B1 = B2 = B3 = B4 = B5 = B1 = 0) against the alternative using the F-test with critical table values. The asymptotic distributions of the F-statistics are non-standard under the null hypothesis of no cointegration relationship between the examined variables, irrespective of whether the variables are purely I (0) or (I) or mutually cointegrated. Pesaran et al. (2001) provide two sets of asymptotic critical values. The first set assumes all variables are I (0), while the second assumes all are I (1). If the calculated F-statistic exceeds the upper bound critical value, the null hypothesis of no cointegration will be rejected. If the computed F-statistics is less than the lower bound critical value, we cannot reject the null of no cointegration. Finally, the result is inconclusive if the computed F-statistic falls within the lower and upper bound critical values.

The global mean annual changes in temperatures of a particular year are clubbed with the global mean temperature in 1880, which was 13.73°C (Hansen et al., 2006) for arriving at the final values of annual global average temperatures in the study. The study used ARDL methods to forecast the annual average globally in three scenarios: Scenario I (1970-2020), Scenario II (1990-2020), and Scenario III (2010-2020), which have been estimated until 2100. Formally, the relationship is expressed as:

$$MAT = B_0 + B_1\, EMS + B_2\, ECY + B_3\, ENI + B_4\, FEC + B_5\, WPY + U_t \qquad (1)$$

The data on CO2-e (excluding land use, land-use change and forestry (LULUCF)) has been gathered, along with data on global mean annual changes in temperatures (land and ocean) from NASA. Further, the data on electricity from coal sources, energy imports, fossil fuel energy consumption, and water productivity was gathered from the World Bank. Table 1 indicates the database used in the study in detail.

Table 1: Database Used in The Study

Name of variable	**Measurement/ scale**	**Data**	**Source**
Mean annual temperature (MAT)	°C	Global mean annual temperature	NASA (2020)
Carbon emission (EMS)	Mean global GHG emission CO2 equivalent (CO2-e)	CO2 equivalent (CO2-e) in Gigatons (Gt)	Crippa et al. (2020); Olivier and Peters (2020); UNFCCC (1990, 202)
Electricity form coal sources (ECY)	As % of total electricity production	World bank	www.worldbank.org
Energy imports (ENI),	As % of energy used	World bank	www.worldbank.org
Fossil fuel energy consumption (FEC)	As % of total energy consumption	World bank	www.worldbank.org
Water productivity (WPY)	As constant 2015 US$ GDP per cubic meter of total freshwater withdrawal	World bank	www.worldbank.org

Sources: The Author's compilation form Data retrieved from NASA (2020), Crippa et al. (2020), Olivier and Peters (2020), UNFCCC (1990, 2021), and The World Bank.

4. Results and Discussion

In this section, the results of the ARDL model, based on equation (1), applied to the time series data from 1970 to 2020 are presented. Table 2 contains the summary statistics of the variables used in the study. Upon examining Table 2, it is evident that the average mean annual temperature is 14.1634 °C, and the mean value of total CO2-e carbon emission (CO2-e) is 25.901 GtCO2-e. The control variables' mean values are 36.73469 (% of total), -0.121747 (% of energy use), 80.91406 (% of total), and 14.16935 (constant 2015 US$ GDP per cubic meter of total freshwater withdrawal), respectively, for electricity from coal sources (ECY), energy imports (ENI), fossil fuel energy consumption (FEC), and water productivity (WPY). Annexure 1 demonstrates that there is no multicollinearity among the explanatory variables.

Table 2: Summary Statistics of The Variables Used in The Study

Variables	**MAT**	**EMS**	**ECY**	**ENI**	**FEC**	**WPY**
Mean	14.1634	25.9021	36.73469	-0.121747	80.91406	14.16935
Median	14.13	23.97817	37.56634	-2.26971	80.46981	13.68124
Maximum	14.75	38.25623	41.11453	20.96904	84.77312	27.44659
Minimum	13.63	15.69085	30.3173	-4.061711	78.71931	3.57058
Std. Dev.	0.297881	69.2.151	3.419628	5.204272	1.607434	5.905566
Skewness	0.158392	0.448094	-0.478086	2.344202	0.990533	0.238429
Kurtosis	2.247817	1.826722	1.847217	8.201158	3.030739	2.762444
Jarque-Bera	1.387774	4.54111	4.673276	102.1524	8.17827	0.591306
Probability	0.49963	0.103255	0.096652	0	0.016754	0.744046
Observations	51	51	51	51	51	51

Source: Author's calculations.

Table 3: Augmented Dickey-Fuller (ADF) Unit Root Test Statistics

Variables	**Level/difference**	**Test Statistics**	**Critical values**		**Decision**
			1%	**5%**	
MAT	At Level	-5.571	-4.15	-3.50	Stationary
EMS	At First difference	-5.043	-4.15	-3.50	Stationary
ECY	At First Difference	-13.020	-4.15	-3.50	Stationary
ENI	At level	-8.577	-4.15	-3.50	Stationary
FEC	At first difference	-8.189	-4.15	-3.50	Stationary
WPY	At First Difference	-7.2018	-4.15	-3.50	Stationary

Source: Author's calculations.

Table 3 presents the outcomes of the unit-root test that utilizes ADF Test Statistics (refer Annexures II). The ADF test statistics value has been calculated solely at trend and intercept. The results of the table reveal that MAT and FEC are stationary at the level. However, other variables like EMS, ENI, ECY, and WPY are nonstationary at the level but become stationary by taking their first difference. The table displays a mix of stationary and nonstationary series at a level in the model, hence justifying the application of ARDL methodology in the model.

Table 4: F-Statistics for Testing the Existence of Long Run Relationship (Diagnostic Tests)

Diagnostic test	**Test**	**Test-Statistics**	**P value**
Akaike Information Criterion	AIC	23.16624*	0.0000
ARDL Bound Test:	F Test	4.73*	0.00101
Serial Correlation	Breusch – Godfrey Text	------	0.8007
Histogram – Normality Test	Jarque- Bera	------	0.9665
Heteroscedasticity	(Breusch-Pagan-Godfrey	------	0.6180

*Note: *, **, and *** indicates statistically significant at 1 per cent level of significance.*
Source: Author's calculations

Table 4 shows the results of the Breusch-Godfrey serial correlation LM Test for autocorrelation. The findings indicate that the model lacks autocorrelation. As the probability value of the observed R square for the LM test is 0.8007, which is greater than 0.05, it is statistically significant. The model's heteroscedasticity was checked using the Breusch-Pagan-Godfrey test, which detects the absence of heteroscedasticity in the model. The observed probability value of R square is 0.6180, greater than 0.05, which confirms the absence of heteroscedasticity. To evaluate the residuals' normality, the J-B test statistics were applied to the model. The results suggest that residuals follow a normal distribution. It further implies that the model is the best fit for the data. Lastly, the table depicts the VAR Lag selection criterion, and in this model, the study chooses 2 lag as the optimum lag as per the Akaike Information Criterion, a popular criterion for selecting optimum lag length (refer to Annexures III & IV).

Table 5: Estimated Coefficients of Mean Annual Temperature

Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Long run analysis				
EMS	0.000017**	0.000006	2.024968	0.0499
ECY	0.053467*	0.012506	4.275414	0.0001
ENI	0.019263*	0.003976	4.845279	0.0000
FEC	0.022264***	0.012786	1.741228	0.0897
WPY	-0.002164	0.002457	-0.880638	0.3840
Constant	10.124479	1.293074	7.829776	0.0000
Cointeq=MAT-(0.00001*EMS+0.05346*ECY+0.01926*ENI+0.02226*FEC-0.0021*WPY+10.1245)				
Short run analysis				
MAT (-1))	0.314551**	0.147041	2.139214	0.0389
EMS)	0.000019**	0.000008	1.887679	0.0667
ECY)	0.065944*	0.017240	3.825112	0.0005
ENI)	0.013593*	0.004560	2.981042	0.0050
FEC)	0.027460***	0.015372	1.786321	0.0820
WPY)	-0.002464	0.004270	-0.577197	0.5672
WPY (-1))	0.011272*	0.003828	2.944635	0.0055
CointEq(-1)	-1.233360*	0.186059	-6.628861	0.0000

*Note: *, ** and *** denote statistically significance at 1 per cent, 5 per cent and 10 per cent level of significance. ARDL (2, 0, 0, 1, 0, 2) selected on the basis of Akakie Information criterion (AIC).*

Source: Author’s calculations

Table 5 contains the estimates of the long-run coefficients of the selected ARDL (2, 0, 0, 1, 0, 2) based on AIC. The relationship between MAT and EMZ is positive and significant at the 1% significance level. The findings reveal that a unit increase in emissions (EMS) usage increases by 0.000012 units in Mean Annual Global Temperature (MAT). Therefore, the mean annual temperature will increase with the increase in total carbon emissions. The coefficient value of emissions (EMS) can be used to forecast mean annual temperature for future periods. The other explanatory variables in the model act as control variables. The results indicate that all control variables, such as electricity (ECY), energy imports (ENI), and fossil fuel energy consumption, are statistically significant in positively influencing MAT. However, it is essential to note that the model can only find a long-run relationship between mean annual temperature and emissions to forecast or find the trend of mean annual temperature over time.

Table 6: Predicted Global Mean Annual Temperature

Year	Expected Temperature (°C) Scenario I	Expected Temperature (°C) Scenario II	Expected Temperature (°C) Scenario III
2030	1.256	1.329	1.3507
2050	1.788	1.816	2.286
2080	2.339	2.632	3.373
2100	2.615	3.165	4.098

Note: The forecasted temperature changes denote the increase in global mean annual temperature compared to the pre-industrial level (1880).

Source: Author's calculations

Table 6 shows a wide variation in the global mean annual temperature increase for all three scenarios. The increase in global mean temperature is more pronounced in 2080, and after that, the predicted rise in global average temperature is set to increase by 2.62°C, 3.17°C and 4.1°C, in Scenario I, Scenario II and Scenario III, respectively by the turn of the century. The expected annual mean temperature increase in all three Scenarios is considerably higher than that of temperature limits sets (1.5°C /2.00°C) in the Paris agreement.

Table 7: Predicted Global Carbon Emission

Year	Expected Carbon Emission (GtCO2-e) Scenario I	Expected Carbon Emission (GtCO2-e) Scenario II	Expected Carbon Emission (GtCO2-e) Scenario III
2030	34.75	45.18	42.04
2050	40.93	57.36	49.63
2080	50.21	75.62	61.01
2100	56.39	87.79	68.60

Source: Author's calculations

Table 7 highlights that the global carbon emission (GtCO2-e) is set to increase in all three scenarios. The increase in global carbon emissions (GtCO2-e) shows a steady increase in all three studied scenarios. The gap has been widening since 2030 in Scenario II compared to Scenario I and Scenario III. The expected annual mean temperature increase in all three scenarios is higher than that of temperature limits sets (1.5°C /2.00°C) in the Paris agreement.

Table 8: Trends of Temperature Limits and Emission Reduction as per Paris Agreement

Year	Current Trends (Scenario III)
Year of exceeding the limit of 1.5 °C	2029 (1.52°C) Corresponding emission level will be 45.64 GtCO2-e
Year of exceeding the limit of 2 °C	2043 (2.046) Corresponding emission level will be 54.89 GtCO2-e
Yearly emission reduction required to maintain at 1.5 °C (Per cent since 2029)	1.02 (% per year)
Yearly emission reduction required to maintain at 2°C (Per cent since 2043)	0.94 (% per year)

Note 1: The forecasted temperature changes years represents the increase in global mean annual temperature compared to the pre-industrial level (1880).

2. The forecasted year and emission reduction are estimated by extrapolations for a particular level/year.

Source: Author's calculations

The Paris Agreement, like the Kyoto Protocol, is in danger of not reaching the Agreement's target, which is too problematic in light of the pledges made by the member countries under the Paris Agreement to determine their NDCs to reduce emissions as per their commitments. Table 8 displays the annual reduction and the year required globally to adhere to the Paris Agreement pledges by the member nations. It is pertinent to mention here again that the Paris Agreement seems to align most of the nations, but their pledges by each country to determine their national targets for emission reduction to manage climate change, limiting it to 1.5-2.0°C by the turn of this century. Given the current global emission trends (2010-2021), the ideal limit of 1.5°C will be crossed in 2029, while the upper limit of 2°C will be surpassed in 2043. The findings are consistent with much research, e.g., NASA (2023) forecasted the global temperature to rise by 2.5°C to 4.5°C; Brown and Caldeira (2017) temperatures could increase by 4.8°C by 2100; Herring (2012) suggested that our planet's average temperature could be between 1.1°C and 5.4°C warmer in 2100; IPCC (2023) 3.3°C to 5.7ºC; Climate Interactive (2023) who forecasted set for a 3.5°C temperature increase by 2100; and Climate Action Tracker (2023) foresaw warming of 3.6°C.

The global emissions trends in the aftermath of the Paris Agreement are alarming, and predicted emissions could be far above the Paris Agreement’s limit (Mor et al., 2023). Further, suppose the Paris parties want to achieve the goal of 1.5°C. In that case, global emissions need to be reduced by 1.02 per cent annually from 2029 till 2100, and compliance with 2°C targets by 2100 needs a straight cut of 0.94 per cent of annual global emissions from 2043 till 2100. Research by UNFCCC (2015) supports our findings and recommends an emissions reduction rate of just 1.6 per cent per year, which today seems daunting.

Moreover, the warming experienced by people in specific regions is typically higher than the average warming, as about 14 per cent of the population will still experience warming exceeding 2°C, and even if current pledges are fully implemented, predicted emissions could see temperatures rise by 2.9°C-3.4°C above pre-industrial levels by 2030, which is far above the 2°C of the Paris climate agreement.

The overall picture of global emissions is very gloomy, and the world is eventually gradually approaching, moving towards the disaster of climate change, which may cause massive loss to our shared resources and the sustainability of this planet. The world looks to technology to deliver its dividends in climate mitigation, and artificial intelligence applications can reduce carbon emissions and revitalize the whole industry (Mor et al., 2021). Therefore, a two-pronged strategy may be cumulatively effective. One prong aims to devise and deploy carbon-mitigating technological solutions at the global level, while the other aims to help developing economies stabilise their emissions. Herein, adoption of knowledge-driven innovation and investment in sustainable development is essential to address climate change, build resilience, and achieve the 17 SDGs (Kopala et al., 2023; Mor & Das, 2023). Apart from the deployment of innovative technological solutions, the participating nations may strictly adhere to their NDCs; the North should transfer the first-hand technology to the South at subsidised rates in a fair manner to help them meet their pledge and gradually shift to no fossil fuel society to achieve the UN sustainable goal by the year 2030.

5. Conclusions

The present endeavour assesses the impact of CO2-e emissions on the global mean annual temperature change increase by employing simple linear regression for 1970-2020. The findings indicate that achieving the desired levels of global warming—maintaining the global mean temperature below 2°C, preferably to 1.5°C, compared to pre-industrial levels set under the Paris Agreement—would be tough. The inferences of the study reveal that given the present levels of global CO2-e emissions, the expected increase in global mean temperature would be 2.62°C in Scenario I (1970-2020), 3.17°C in scenario II (1990-2020) and 4.1°C in scenario III (2010-2020) higher than the temperature compared to that of pre-industrial levels by 2100. The results show that the forecasted global average temperature increase is considerably higher than the temperature limit set under the Paris Agreement by the turn of the century.

Further, the trend analysis predicts that the gap between the expected annual mean temperature increase, and the temperature limits set in the Paris Agreement will increase faster from 2030 onwards. Therefore, the study calls for a straight reduction in global annual emissions by 1.02 per cent and 0.94 per cent w.e.f. from 2029 and 2043, respectively, till 2100 in order to adhere to the Paris Agreement goal (1.5°C / 2°C) and to maintain a sustainable planet. It is challenging to say anything about the climate management efforts of the Paris parties and achieving global warming levels of 1.5°C or 2°C still seems like a dream for the world.

The inferences of this research may be taken as a caution, as these trends are based on secondary data mined from various databases using selected variables. Further, these are only early trends; it is challenging to forecast anything substantial as the parties of the Paris Agreement are revising and reviewing their pledges/emission reduction targets for the climate management of 1.5°C (or 2°C). Further, the countries participating in the Paris Agreement are still preparing action plans for mitigating, adapting, and developing long-term low GHG emission strategies for a liveable planet. Further, the study focuses only on carbon emission equivalents and the non-carbon sources of emissions, which were not under consideration. Further research may take emissions from carbon and non-carbon sources for more precise inferences besides using longitudinal data on other emission forms.

References

Böhringer, C. (2003). The Kyoto protocol: A review and perspectives. *Oxford Review of Economic Policy*, *19*(3), 451-466.

Brown, P. T., & Caldeira, K. (2017). Greater future global warming inferred from earth's recent energy budget. *Nature*, *552*(7683), 45-50.

Climate Action Tracker. (2023). *2100 warming projections: Emissions and expected warming based on pledges and current policies* [Graph]. Retrieved from https://climateactiontracker.org/global/temperatures/

Climate Interactive. (2023). *Climate scoreboard*. Retrieved from https://www.climateinteractive.org/ci-topics/climate-energy/scoreboard/

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J. G. J., & Vignati, E. (2020). *Fossil CO2 emissions of all world* Countries-2020 report, EUR 30358 EN. Publications Office of the European Union, Luxembourg: Retrieved from https://publications.jrc.ec.europa.eu/repository/handle/JRC121460

Danish. (2020). Moving toward sustainable development: The relationship between water productivity, natural resource rent, international trade, and carbon dioxide emissions. *Sustainable Development*, *28*(4), 540–549.

Doeffinger, T., & Hall, J. W. (2020). Water stress and productivity: An empirical analysis of trends and drivers. *Water Resources Research*, *56*(3). e2019WR025925.

Dulal, A., Yao, X., Barker-Gibb, M., Tachega, M. A., Ge, S., Li, H., Dulal, A., Yao, X., Barker-Gibb, M., Tachega, M. A., Ge, S., & Li, H. (2021). Impact of renewable energy on carbon dioxide emission reduction in Bangladesh. *Journal of Power and Energy Engineering*, *9*(5), 134–165.

Eurostat. (2022, June 24). CO2 emissions from energy use up by more than 6% in 2021. Luxembourg: European Commission. Retrieved from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220624-1

Falkner, R. (2016). The Paris agreement and the new logic of international climate politics. *International Affairs*, *92*(5), 1116-1125.

Gasparotto, J., & Da Boit Martinello, K. (2021). Coal as an energy source and its impacts on human health. *Energy Geoscience*, *2*(2), 113–120.

Gore, T. (2020). *Confronting carbon inequality: Putting climate justice at the heart of the COVID-19 recovery*. Retrieved from https://policy-practice.oxfam.org/resources/confronting-carbon-inequality-putting-climate-justice-at-the-heart-of-the-covid-621052/

Grunewald, N., & Martinez-Zarzoso, I. (2016). Did the Kyoto protocol fail? An evaluation of the effect of the Kyoto protocol on CO2 emissions. *Environment and Development Economics*, *21*(1), 1-22.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D. W., & Medina-Elizade, M. (2006). Global temperature change. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(39), 14288–14293.

Herring, D. (2012, March 6). *Climate change: Global temperature projections*. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections

Hong, B.D. & Slatick, E. R. (1994). Carbon dioxide emission factors for coal. *Quarterly Coal Report*, *January-April* (1), 1–18.

Horowitz, C. A. (2016). Paris agreement. *International Legal Materials*, *55*(4), 740-755.

Huang, W. M., Lee, G. W. M., & Wu, C. C. (2008). GHG emissions, GDP growth and the Kyoto protocol: A revisit of environmental Kuznets Curve hypothesis. *Energy Policy*, *36*(1), 239-247.

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2023). *Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In Climate Change 2022 - Mitigation of Climate Change*. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2023). *Summary for Policymakers. Synthesis report of the IPCC Sixth Assessment Report*. Retrieved from https://www.ipcc.ch/report/ar6/syr/

Jakob, M., Steckel, J. C., Jotzo, F., Sovacool, B. K., Cornelsen, L., Chandra, R., Edenhofer, O., Holden, C., Löschel, A., Nace, T., Robins, N., Suedekum, J., & Urpelainen, J. (2020). The future of coal in a carbon-constrained climate. Nature Climate Change, 10(8), 704–707.

Janetschek, H., Brandi, C., Dzebo, A., & Hackmann, B. (2020). The 2030 agenda and the Paris agreement: Voluntary contributions towards thematic policy coherence. *Climate Policy*, *20*(4), 430-442.

Jernnäs, M., & Linnér, B. O. (2019). A discursive cartography of nationally determined contributions to the Paris climate agreement. *Global Environmental Change*, *55*, 73-83.

Karki, U., & Rao, P. (2023). Techno-economic analysis of the water, energy, and greenhouse gas emissions impacts from the adoption of water efficiency practices in the U.S. manufacturing sector. *Resources, Conservation and Recycling*, *196*.

Kopala, M. R., Ashta, A., Mor, S., & Parekh, N. (2023). The co-evolution of India's policy on science, technology, and innovation with university education: The need for innovation in higher educational institutions. *Space and Culture, India*, *11*(2), 6-17.

Li, J., Irfan, M., Samad, S., Ali, B., Zhang, Y., Badulescu, D., & Badulescu, A. (2023). The relationship between energy consumption, CO2 emissions, economic growth, and health indicators. *International Journal of Environmental Research and Public Health*, *20*(3), 1-20.

Lindsey, R. & Dahlman, L. (28 June, 2022). *Climate change: Global temperature. National Oceanic and Atmospheric Administration*. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Mann, M. E. (2023, September 24). *Global warming*. Retrieved from Encyclopaedia Britannica https://www.britannica.com/science/global-warming

Marston, T., Lamsal, L., Ancona, G.H., Caldwell, Z., Richter, P.D., Ruddell, B.L., Rushforth, B.R., & Frankel Davis, K. (2020). Reducing water scarcity by improving water productivity in the United States. *Environmental Research Letters*, *15*(9).

Martins, T., Barreto, A. C., Souza, F. M., & Souza, A. M. (2021). Fossil fuels consumption and carbon dioxide emissions in G7 countries: Empirical evidence from ARDL bounds testing approach. *Environmental Pollution*, *291*.

Mella, P. (2022). Global warming: Is it (im)possible to stop it? The systems thinking approach. *Energies*, *15*(3), 1-33.

Mor, S. & Das, M. (2023). G-20 and sustainable development: A way forward. *Space and Culture, India*, *11*(2), 1-5.

Mor, S. & Ghimire, M. (2022). Transparency and nationally determined contributions: A review of the Paris agreement. *Interdisciplinary Journal of Economics and Business Law*, *11*(2), 106–119.

Mor, S. (2014). Estimation of environmental Kuznets curve for India. *EPRA International Journal of Environmental Economics, Commerce and Educational Management*, *1*, 10–16.

Mor, S. (2017a). Climate change and land revenue: Evidences from Indian agriculture. *Disaster Advances*, *10*(12), 21–27.

Mor, S. (2017b). Impacts of climate variability on the wheat production in India. *Disaster Advances*, *10*(7), 12–18.

Mor, S., Madan, S., & Prasad, K. D. (2021). Artificial intelligence and carbon footprints: Roadmap for Indian agriculture. *Strategic Change*, *30*(3), 269–280.

Mor, S., Ranjan, A., Madan, S., & Ghimire, M. (2023). Kyoto protocol and Paris agreement: Transition from bindings to pledges – A Review. *Millennial Asia*, 15(4); 691-711.

Mor, S. & Singh, G. (2019). Does Growth affect environment? Evidence from the World. *Journal of International Economics*, 10(1): 42-49.

Mor, S. and Jindal S. (2012). Estimation of Environmental Kuznets Curve and Kyoto Parties: A Panel Data Analysis. *International Journal of Computational Engineering and Management*, 15, 5-9.

National Aeronautics and Space Administration (NASA). (2023). Is it too late to prevent climate change? – Climate change: Vital signs of the planet. Retrieved from https://climate.nasa.gov/faq/16/is-it-too-late-to-prevent-climate-change/

National Aeronautics and Space Administration (NASA). (2020). *Climate Change: Vital Signs of the Planet, 2020*. Retrieved from https://climate.nasa.gov/vital-signs/global-temperature/

National Centers for Environmental Information (NCEI). (2021). Global Climate Report. Retrieved from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202113

National Oceanic and Atmospheric Administration (NOAA). (2021). *NOAA index tracks how greenhouse gas pollution amplified global warming in 2020 - Welcome to NOAA Research*. Retrieved from https://research.noaa.gov/article/ArtMID/587/ArticleID/2759/NOAA-index-tracks-how-greenhouse-gas-pollution-amplified-global-warming-in-2020

Olivier, J. G. J., & Peters, J. A. H. W. (2020). *Trends in global CO2 and total greenhouse gas emissions: 2020 Report*. Retrieved form https://www.pbl.nl/en/publications/trends-in-global-co2-and-total-greenhouse-gas-emissions-2020-report

Oxfam International. (2020). Confronting carbon inequality in the European Union. Oxfam Media Briefings. Retrieved from https://www.oxfam.org/en/research/confronting-carbon-inequality-european-union

Pan, A., Xu, S., & Zaidi, S. A. H. (2024). Environmental impact of energy imports: Natural resources income and natural gas production profitability in the Asia-Pacific economic cooperation countries. *Geoscience Frontiers*, *15*(2).

Panghal, A., & Mor, S. (2020). Climate sensitivity of rice crop in India. *Plant Cell Biotechnology and Molecular Biology*, *21*(55–56), 76–88.

Panghal, A., & Mor, S. (2020). Climate variability and wheat crop yield: Forecasting Indian scenario till 2100 AD. *Disaster Advances*, *13*(11), 31–41.

Pesaran, M. H., & Smith, R. P. (1998). Structural analysis of cointegrating VARs. *Journal of Economic Surveys, 12*(5), 471-505.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326.

Rosen, A. M. (2015). The wrong solution at the right time: The failure of the Kyoto protocol on climate change. *Politics and Policy*, *43*(1), 30-58.

Shishlov, I., Morel, R., & Bellassen, V. (2016). Compliance of the parties to the Kyoto protocol in the first commitment period. *Climate Policy*, *16*(6), 768-782.

United Nations Framework Convention on Climate Change (UNFCCC). (1990). *Highlights from KEY GHG DATA- Greenhouse Gas (GHG) Emissions Data for 1990-2003*. Retrieved from https://unfccc.int/resource/docs/publications/key_ghg.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (2015). *Synthesis report on the aggregate effect of the intended nationally determined contributions*. Retrieved from http://unfccc.int/focus/indc_portal/items/9240.php

United Nations Framework Convention on Climate Change (UNFCCC). (2015). *The Paris Agreement*. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations Framework Convention on Climate Change (UNFCCC). (2021). *NDC Synthesis Report*. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs/ndc-synthesis-report#eq-4

Voumik, L. C., Islam, M. A., Ray, S., Mohamed Yusop, N. Y., & Ridzuan, A. R. (2023). CO2 emissions from renewable and non-renewable electricity generation sources in the G7 countries: Static and dynamic panel assessment. *Energies 2023*, 16(3), 1044.

Wirth, D. A. (2017). The Paris agreement as a new component of the UN climate regime. *International Organisations Research Journal*, *12*(4), 185-214.

World Meteorological Organization. (2019). WMO Statement on the State of the Global Climate in 2018. World Meteorological Organization (WMO-No. 1233) Geneva, Switzerland. https://library.wmo.int/idurl/4/56141

World Meteorological Organization (WMO). 2022. *State of the global climate 2021*. Retrieved from https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate

Young, O. R. (2016). The Paris agreement: Destined to succeed or doomed to fail? *Politics and Governance*, *4*(3), 124-132.

Annexures

Annexure 1: Correlation matrix

Variables	MAT	EMS	ECY	ENI	FEC	WPY
MAT	1.000000	0.935126	0.862281	0.505234	-0.48002	0.407324
EMS	0.935126	1.000000	0.879461	0.460925	-0.381898	0.450750
ECY	0.862281	0.879461	1.000000	0.170013	-0.566592	0.392716
ENI	0.505234	0.460925	0.170013	1.000000	-0.274444	0.194326
FEC	-0.48002	-0.381898	-0.566592	-0.274444	1.000000	0.130982
WPY	0.407324	0.450750	0.392716	0.194326	0.130982	1.000000

Source: Author's calculations

Annexure II: F-Statistics for Testing the Existence of Long Run Relationship

ARDL Bound Test: 4.73*		
Critical Bounds value	**I(0) Bound**	**I(1) Bound**
10%	2.26	3.35
5%	2.62	3.79
2.50%	2.96	4.18
1%	3.41	4.68

*Note: *indicates that F-Statistics is significant at 1 per cent and 5 per cent level of significance as the value is greater than upper bound value*

Source: Author's calculations

Annexure III: VAR Lag Order Selection Criteria

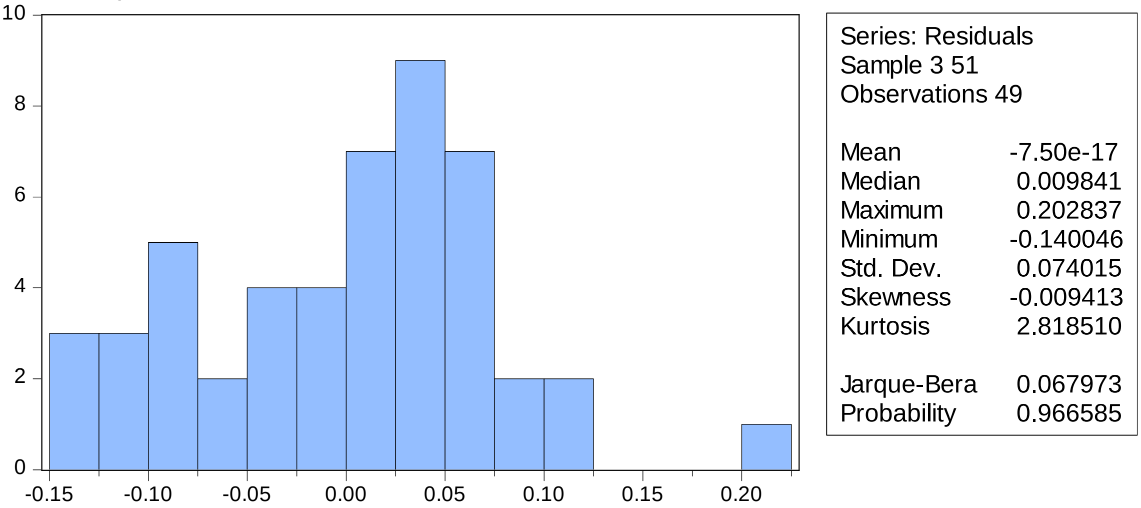
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-732.2971	NA	3515359.	32.09987	32.33839	32.18922
1	-491.1659	408.8746	477.3068*	23.18113	24.85076*	23.80658*
2	-454.8235	52.14351*	509.7146	23.16624*	26.26698	24.32779
3	-422.6222	37.80150	749.1344	23.33140	27.86325	25.02906
4	-384.8709	34.46854	1113.431	23.25526	29.21822	25.48902

*Note: *Indicates lag order selection criteria LR- LR test statistics (sequential modified), FPE- Final Prediction Error, AK- Akaike Information Criterion, SC – Schwarz information Criterion, HQ – Hannan- Quin -Information criterion*

Source: Author's calculations

Annexure IV: Residual diagnostic test

Normality



Jarque Bera 0.067973 and p value 0.966585 greater than 0.05. hence data is normal.

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.223623	Prob. F(2,36)	0.8007
Obs*R-squared	0.601281	Prob. Chi-Square(2)	0.7403

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.753750	Prob. F(10,38)	0.6706
Obs*R-squared	8.110625	Prob. Chi-Square(10)	0.6180
Scaled explained SS	4.435220	Prob. Chi-Square(10)	0.9256

Source: Author’s calculations