PREDICTION OF CARBON DIOXIDE (CO_2) EMISSIONS IN BANGLADESH BY USING ARIMA METHOD

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Abstract— In this research we employments an Autoregressive Integrated Moving Average (ARIMA) model to estimate the size of the carbon dioxide emission rate after 20 years using yearly periodic data on carbon dioxide emissions in Bangladesh from 1946 to 2021. To analyze our time series data, we used the ARIMA (1,2,1) model, which was selected based on Akaike's Information Criterion (AIC). Using our chosen framework, we calculated the projected assessment of carbon dioxide emissions in Bangladesh over the next 23 years, from 2023 to 2045. According to the study's findings, CO2 emissions in Bangladesh are most likely to rise, exposing the country to climate-related challenges. There have been five policy prescriptions proposed.

Keywords— ARIMA model, carbon dioxide emission, estimate, Bangladesh.

I. INTRODUCTION

Emission of carbon-dioxide (CO2) from living beings, natural disasters and other sources of nature can be balanced by the utilization of CO2 by plants and oceans [1]. The amount of CO2 in the atmosphere is increasing day by day due to industrialization, utilization of fossil fuels, domestic uses etc. which largely contribute to the green house effects that may lead to global warming [1, 2]. According to Intergovernmental panel on climate change (IPCC) 2007, it is stated that CO2 is the most prevailing greenhouse gas (GHGs) which accounted for 77% of the total GHGs [3]. Now-a-days, climate change due to CO2 emission is most burning issue in the world. It is estimated that with doubling the emission of CO2, the global temperature will increase about 3oC to 4oC [4].In developing countries, like Bangladesh, emission of CO2 also contributes to global warming and it’s stated that about 16% of CO2 is emitted from developing countries due to utilization of fossil fuels [5].

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However, the rate of CO2 emission in developing countries is much lower than developed countries [1]. The impact of climate change on Bangladesh is great and Bangladesh is most vulnerable country in the world [3]. The rate of CO2 emission in Bangladesh is about 6.7% which is much higher than the total energy consumption and GDP [6]. Global warming due to CO2 emission causes increasing the sea-level. According to IPCC 2007, in Bangladesh the rate of sea-level rise is about 1.5mm per year which will cause greater loss of land, 8% of rice and 32% of wheat production by the year 2050 [3]. Coastal region of Bangladesh will suffer much for this effects [7]. So, forecasting of CO2 emission in Bangladesh is important to understand the emission rate in past and predict the rate of emission in future. It is important to create consciousness among public to solve ecological related difficulties.

The autoregressive integrated moving average (ARIMA) model is widely used to estimate CO2 emission. Rahman and Hasan (2017) [1] found that the ARIMA (0, 2, 1) model was the greatest model for forecasting and predicting carbon dioxide in Bangladesh using yearly data spanning 44 years, from 1972 to 2014. But we have found the ARIMA(1, 2, 1) is the best model using yearly periodic data from 1946 to 2021. In a different study on Bangladesh, Hossain et al. (2017) [2] used the Box-Jenkins ARIMA technique to analyze carbon dioxide emissions over the years 1972 to 2013 and came to the conclusion that the ARIMA (8, 1, 3), ARIMA (12, 2, 12), and ARIMA (5, 1, 5) are the best fit models for forecasting CO2 emission from LFC, GFC, and SFC as opposed to the other forecasting methods, ANN and HWNS models.

II. METHOD AND MATERIALS

A. Data Source:

The yaerly periodic data on carbon dioxide discharges in Bangladesh from 1946 to 2021 were considered in this study. The annual secondary data were gathered from the World Data Bank (https://data.worldbank.org) and our world in data (https://ourworldindata.org/), and the $ARIMA$ (1,2,1) model was used to forecast the next 20 years carbon dioxide emissions (metric tons per capita).

B. ARIMA Model

ARIMA is an established method for analyzing non-stationary time - series data. Unlike most regression models, the ARIMA structure allows yearly data to be explicated by their past or lag values as well as stochastic error terms**[1].** These methods are commonly referred to as ARIMA models because they combine autoregressive (AR), integration (I) - referring to the contrary process of differencing - and moving average (MA) processes to produce the forecast**[8.]**

The Autoregressive Integrated Moving Average model is symbolized by $ARIMA\ (p, d, q)$, here "p" represents the order of the auto regressive process, "d" represents the order of the data stationary process, and "q" characterizes the order of the moving average process. The common structure of the $ARIMA\ (p, d, q)$ can be chosen to write as **[9].**

$$\Delta^d y_t = \delta + \theta_1 \Delta^d y_{t-1} + \theta_2 \Delta^d y_{t-2} + \ldots. + \theta_p y_{t-p} + e_{t-1} \alpha e_{t-1} - \alpha_2 e_{t-2} \alpha_q e_{t-2} \quad \ldots(1)$$

Here, Δ^d indicates differencing of order d, i.e., $\Delta y_t = y_t - y_{t-1}$, $\Delta^2 y_t = \Delta y_t - \Delta y_{t-1}$ and so forth. $y_{t-1} \ldots. y_{t-p}$ are first remarks (lags), $\delta, \theta_1, \ldots, \theta_p$ are parameters (constant and coefficient) to be projected parallel to regression coefficients of the Auto Regressive process (AR) of order "p" symbolized by $AR(p)$ and can be expressed as,

$$Y = \delta + \theta_1 y_{t-1} + y_{t-2} + \cdots \ldots. + \theta_p y_{t-p} + e_t \quad \ldots(2)$$

here, e_t is forecast error, expected to be individually dispersed across period with mean θ and variance $\theta_2 e, e_{t-1}, e_{t-2} \ldots. e_{t-p}$ are past forecast errors, $\alpha_1 \ldots \ldots \alpha_q \cdots$ are indicates moving average (MA) coefficient. Whereas MA method of order q (i.e.) $MA\ (q)$ can be expressed as,

$$Y_t = e_t - \alpha_1 e_{t-1} - \alpha_2 e_{t-2} - \cdots - \alpha_q e_{t-q} \quad \ldots(3)$$

III. RESULT

A. Data Analysis

In this paper, to analyze annual carbon dioxide time series data we select ARIMA (1,2,1) model according to information of **table-1.** From table-1 we get our model selection criteria Akaike's Information Criterion (AIC). In **figure-1** and **figure-2** we represent Autocorrelation Function (ACF) Plot and Partial Autocorrelation Function (PACF) Plot also in **figure-3** and **figure-4** we plot ACF– Residuals and PACF– Residuals; where Significance Limit Alpha = 0.05 respectively. The ACF and PACF figures, as well as the residuals- ACF and residuals- PACF figures, show that there is no vital spike in the original series, indicating that there are no significant effects of Auto-Regressive and Moving Average in the original series, indicating that the carbon dioxide secretion series is stationary without difference.

After declaring the sequences stationary, various parametric arrangements of the ARIMA (1, 2, 1) model were applied to analyze the 76-year data (1946 to 2021) of carbon dioxide emissions and the above-mentioned selection criteria. **Table-2, 3,** repent the Parameter Estimates by ARIMA (1,2,1) model and Model Statistics information respectively.

B. Forecast

Projected value of carbon dioxide emission (metric tons per capita) for out-of-sample forecast accuracy evaluation are shown - on **table 5** and **graph-5** represents Annual Carbon dioxide emission (Per Capita) by ARIMA Time Series Forecasting Chart 95.0% Prediction Intervals from 2022 to 2045. With a projection range of 23 years, i.e., 2022 – 2045; Figure 5 and Table 5, noticeably indicate that CO2 emissions in Bangladesh are continuously increasing. By 2045, Bangladesh's carbon emissions will be 0.923981796 metric tons per capita. This indicates that Bangladesh will continue to confront the difficulties of climate change, global warming and a clean and healthy environment.

IV. TABLES

*A. **Table-1:** Identification information of Model Selection*

ARIMA Model Summary	
AR Order (p)	1
I Order (d)	2
MA Order (q)	1
SAR Order (P)	0
SI Order (D)	0
SMA Order (Q)	0
Seasonal Frequency	1
Include Constant	0
No. of Predictors	0
Model Selection Criterion	AIC

*B. **Table-2:** Parameter Estimates by ARIMA (1,2,1) model*

Parameter Estimates				
Term	**Coefficient**	**SE Coefficient**	**T**	**P**
AR_1	- 0.302521211	0.117445676	2.57584	**0.0121**
MA_1	0.825779658	0.058245729	14.17751	**0.0000**

C. ***Table-3:*** *Model Statistics information*

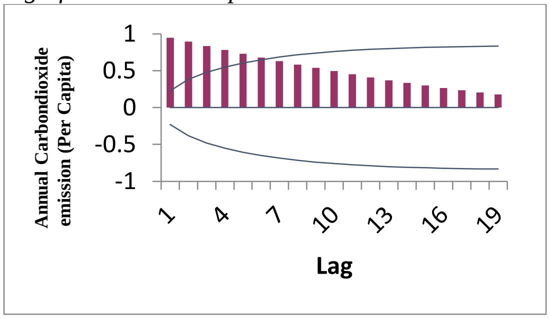
ARIMA Model Statistics	
No. of Observations	76
DF	72
StDev	0.009292513
Variance	8.63508E-05
Log-Likelihood	241.3109922
AICc	-476.2791273
AIC	-476.6219845
BIC	-469.7097892

D. ***Table-4:*** *Metric value in Sample (Estimation) One-Step-Ahead Forecast*

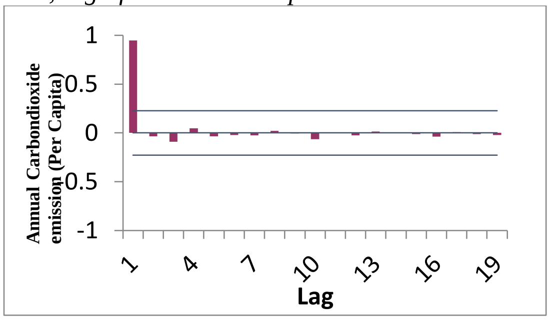
Metric	In-Sample (Estimation) One-Step-Ahead Forecast
N	74
RMSE	0.00922446
MAE	0.00609683
MAPE	6.317377961
MASE	0.734463162

V. Graphs

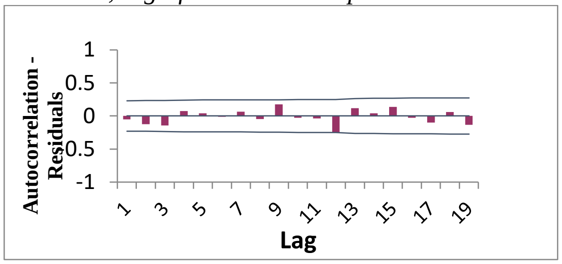
A. ***Figure1:*** *Autocorrelation Function (ACF) Plot Significance Limit Alpha = 0.05*



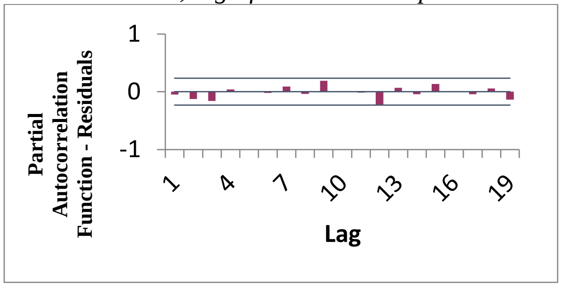
B. ***Figure-2:*** *Partial Autocorrelation Function (PACF) Plot; Significance Limit Alpha = 0.05*



C. ***Figure-3:*** *Autocorrelation Function (ACF) Plot – Residuals; Significance Limit Alpha = 0.05*



D. ***Figure-4****: Partial Autocorrelation Function (PACF) Plot – Residuals; Significance Limit Alpha = 0.05*



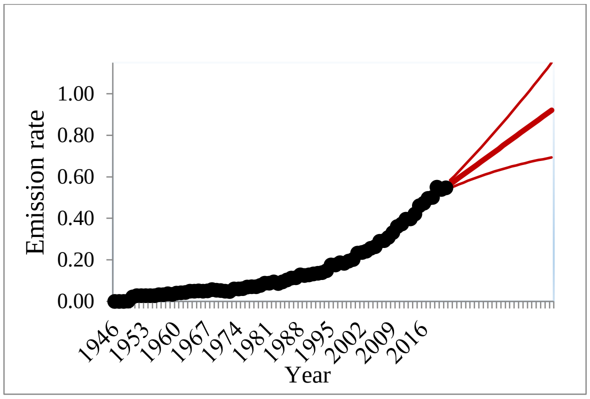
VI. Forecast Table and Graph

A. ***Table-5:*** *Projected value of carbon dioxide emission (metric tons per capita) for out-of-sample forecast accuracy evaluation.*

Period	Forecast	Lower 95.0% PI	Upper 95.0% PI
2022	0.568042144	0.549530509	0.586553779
2023	0.582826078	0.5582686	0.607383555
2024	0.598542082	0.56682011	0.630264055
2025	0.613976116	0.575307838	0.652644393
2026	0.629495451	0.583599442	0.67539146
2027	0.644988981	0.591659791	0.698318171
2028	0.660490318	0.599474665	0.721505971
2029	0.675989293	0.607036259	0.744942327
2030	0.691488982	0.614343695	0.76863427
2031	0.706988456	0.621398168	0.792578743
2032	0.722487994	0.628202681	0.816773307
2033	0.737987513	0.634760989	0.841214038
2034	0.753487038	0.641077307	0.865896769
2035	0.768986561	0.647156033	0.89081709
2036	0.784486085	0.653001609	0.91597056
2037	0.799985608	0.658618434	0.941352783

2038	0.815485132	0.664010805	0.966959459
2039	0.830984655	0.669182895	0.992786416
2040	0.846484179	0.67413873	1.018829628
2041	0.861983702	0.678882185	1.04508522
2042	0.877483226	0.683416983	1.071549469
2043	0.892982749	0.687746694	1.098218805
2044	0.908482273	0.691874741	1.125089805
2045	0.923981796	0.695804406	1.152159187

B. ***Figure-5:*** *Forecast: Annual Carbon dioxide emission (Per Capita) by ARIMA Time Series Forecasting Chart95.0% Prediction Intervals*



VII. Policy Implications

The ARIMA forecasting method was used in the study, and the model results and forecasts were observed and analyzed. The following policy implications were identified by the study:

i. Bangladesh should reduce its reliance on fossil fuels.
ii. Energy-saving technologies that are more efficient are always in demand.
iii. It is also suggested that renewable energy be used.
iv. There is an ongoing need to educate the Bangladeshi people about the significance of low pollution stages. The Government of Bangladesh and other relevant partners should conduct well-organized awareness campaigns in this regard.
v. The Bangladesh government should enact policies to reduce pollution, such as raising taxes on contaminating companies, particularly those that use fossil fuels in their manufacturing processes.

For all of these policy instructions to be effective, energy controlling, energy auditing, and energy conservation policies must be in place. Energy management is the process of reducing excess energy demand, whereas energy auditing is the process of measuring energy consumption based on its discrete functions[11]. Energy conservation, particularly the conservation of fossil fuels, is intricately linked to environmental concerns such as global warming. A better future environment will necessitate greater collaboration among parties for collaborative efforts and increased awareness of the need to reduce emissions.

VIII. Conclusion

The ARIMA (1, 2, 1) model, according to the findings, is not only constant, but also the best method for predicting annual overall CO2 in Bangladesh for the next 23 years. Bangladesh's total CO2 emissions will be around 0.923981796 metric tons per capita by 2045, according to the model. This poses a threat to Bangladeshi environmental economists, especially those concerned about climate change and global warming.The study's findings are critical for the government of Bangladesh, mainly in terms of medium and long-term planning. It is the responsibility of every citizen and every industry to achieve significant success in reducing carbon dioxide emissions, whereas the government residues the main regulator and initiator of working together to maintenance for the environment in the forthcoming. Because global warming has such a large impact on the world, the study's findings can be applied to any country, particularly in the creation and execution of energy audit concepts, power controlling, and energy conservation performs. Conservational safety is now synonymous with a brighter future for all.

References

[1] A. Rahman and M. M. Hasan, "Modeling and forecasting of carbon dioxide emissions in Bangladesh using Autoregressive Integrated Moving Average (ARIMA) models," *Open Journal of Statistics,* vol. 7, no. 4, pp. 560-566, 2017.

[2] A. Hossain, M. A. Islam, M. Kamruzzaman, M. A. Khalek, and M. A. Ali, "Forecasting carbon dioxide emissions in Bangladesh using Box-Jenkins ARIMA models," *Department of Statistics, University of Rajshahi,* 2017.

[3] M. L. Parry, O. Canziani, J. Palutikof, P. Van der Linden, and C. Hanson, *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC*. Cambridge University Press, 2007.

[4] V. Reddy, K. Reddy, and B. Acock, "Carbon dioxide and temperature interactions on stem extension, node initiation, and fruiting in

cotton," *Agriculture, Ecosystems & Environment,* vol. 55, no. 1, pp. 17-28, 1995.

[5] N. Nakicenovic, "Energy strategies for mitigating global change," 1992.

[6] M. S. K. Sarkar, S. Sadeka, and M. M. H. Sikdar, "Energy consumption and CO2 emission in Bangladesh: trends and policy implications," *Asia Pacific Journal of Energy and Environment,* vol. 5, no. 1, pp. 41-48, 2018.

[7] A. Rahman, M. J. H. Jiban, and S. A. Munna, "Regional variation of temperature and rainfall in Bangladesh: estimation of trend," *Open Journal of Statistics,* vol. 5, no. 07, p. 652, 2015.

[8] E. George, G. M. Jenkins, and G. C. Reinsel, *Time series analysis: forecasting and control*. Wiley, 1970.

[9] G. G. Judge, "Introduction to the Theory and Practice of Econometrics," 1982.

[10] G. E. Box, G. M. Jenkins, G. C. Reinsel, and G. M. Ljung, *Time series analysis: forecasting and control*. John Wiley & Sons, 2015.

[11] W. G. Bonga and F. Chirowa, "Level of Cooperativeness of Individuals to Issues of Energy Conservation," *Available at SSRN 2412639,* 2014.

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