# Using the Box-Jenkins ARIMA Approach for Long-term Forecasting of $CO_2$ Emissions in Morocco

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Abstract: The Box-Jenkins ARIMA approach is one of the most essential methods to predict the variable carbon dioxide $CO_2$ value with a proper model to describe the time variation of past data, and ensure security and environmental protection (Wang, T, 2016). This study aimed to predict carbon dioxide emissions in Morocco over the period 1928-2020, using the Box-Jenkins methodology, by building an econometric model for forecasting carbon dioxide ($CO_2$) emissions in Morocco during 1928-2020. Our study concluded that the time series was stationary at the first difference. After examination, analysis, and comparison according to the Box-Jenkins methodology through divers statistical tests, we have been proposed and building the best econometric model to forecasting carbon dioxide ($CO_2$) emissions in Morocco from the form ARIMA (2,1,1), Using the proposed econometric model, our study concluded an estimate of the yearly forecast of carbon dioxide ($CO_2$) emissions in Morocco during the period between 2021-2040 which was Continuously increasing.

## 1 INTRODUCTION

Over the last few years, climate change is a significant issue on the global political agenda due to global warming (Nyoni et al. 2019). The $CO_2$ emitted by human activities is primarily due to the combustion of fossil fuels and deforestation (Daniel A. Vallero, 2016). Based on international statistics, the aviation and transport sector are most of the reasons for the increase in GHGs over the last decade, while other sectors have shown negative trends: (Daniel A. Vallero, 2016). Prediction of future behaviour of time series is one of the crucial topics of statistical sciences, due to its necessity in all areas of life, and its importance for the human element, governments, and organizations in the planning and implementation of the process of economic development (Daniel A. Vallero, 2016).

Forecasting $CO_2$ emissions is an indispensable part of a green energy economy (Pao et al, 2012). It is essential to have a more in-depth view of the past trajectory of Morocco's $CO_2$ emissions to reliably forecast its future emissions (Pao et al, 2012).

This paper seeks to predict the evolution of carbon dioxide emissions in Morocco during the next two decades, 2021-2040 (Daniel A. Vallero, 2016). The accuracy and validity of the ARIMA forecasting method were tested by matching actual data with forecast data (Nyoni et al, 2019).

The rest of the paper is structured as follows: Section 2 presents a brief review of the literature relevant to our research. Section 3 introduces the methodology analysis. Section 4 sums up the data. Empirical and predictive results are provided in Section 5. Finally, the last section contains concluding remarks.

## 2 LITERATURE REVIEW

In the literature, many articles use different approaches such as time series econometrics, ANNs, hybrids, etc. From various fields of engineering, economics, science and, technology.

(Rahman and Hasan, 2017) used forty-four years of time series data between 1972 and 2015 through the use of ARIMA model, and they found that ARIMA (0, 2, 1) model is the most appropriate model to predict carbon dioxide in Bangladesh.

In other research on Bangladesh, (Hossain et al, 2017) forecasted the carbon dioxide emissions in Bangladesh based on Box-Jenkins ARIMA from



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1972 to 2013, and they identified that ARIMA (12, 2, 12), ARIMA (8, 1, 3) are the most appropriate models for predicting $CO_2$ emissions compared to the other forecasting methods.

In China, (Nyoni. T, Chipo. M; 2019) forecasted $CO_2$ emissions in the period 1960-2017, by using Jenkins-Box (ARIMA) methodology, and the study led to the selection of the most suitable model ARIMA (1,2,1), to predict the total $CO_2$ emissions in China in the coming ten years.

(Jamii and Maaroufi, 2021) predicted electrical energy consumption using the ARIMA approach. The most significant results indicate that the ARIMA (1,1,1) model is the most appropriate model for predicting electricity consumption in Morocco, and among the results they found, an expected increase in electricity consumption in Morocco by the end of 2030.

(Mitkov et al, 2019) predicted the energy consumption of the Islamic Republic of Afghanistan from 2001 to 2018, using the linear ARIMA model. The results showed that energy demand would continue to increase towards the end of 2024.

(Sangeetha and Amudha, 2018) predicted $CO_2$ emissions in India, and their results illustrated that the PSO method could achieve a very efficient and accurate estimation compared to the MLR model.

In Morocco, (Nafil et al, 2020) investigate three forecasting methods, namely; ARIMA, Temporal causality modelling, and Exponential smoothing, to calculate the energy demand forecasts of Morocco in 2020.

This study will apply the ARIMA approach to model and forecast $CO_2$ emissions in Morocco.

# 3 METHODOLOGY

## 3.1 ARIMA Model

The ARIMA model is a univariate model that tends to identify a single variable as an autoregressive integrated moving average process (Awe et al, 2020). It includes a composition of three kinds of random processes, the performance of which is expressed as ARIMA (p, d, q), where p is the order of the autoregressive process AR (p), d is the degree of integration of the process I (d), and q is the order of the moving average MA (q) (Cheikh Sarr et al, 2021). The ARIMA (p, d, q) model is generally organized as follows:

$$Y_{t-1} - Y_t = C + \varepsilon_t \tag{1}$$

Where, t is a white noise perturbation term. Then, $Y_t$ is then considered to be generated by an integrated first-order process, and it is notated as I (1). Compactly, the model can be written as:

$$\nabla Y_t = C + \varepsilon_t \tag{2}$$

Where,

$$\nabla = 1 - B \tag{3}$$

Likewise, an integrated process of order d is indicated by I(d) and can be expressed as follows:

$$\nabla^d = C + \varepsilon_t \tag{4}$$

The ARIMA process of order p, d, and q is given as ARIMA (p, d, q), and can be represented compactly as follows:

$$\varphi(\mathrm{B})\, \nabla^d Y_t = C + \theta(B)\varepsilon_t \tag{5}$$

# 4 DATA COLLECTION

This study is based on 92 years of observations (i.e., 1928 - 2020) of CO2 annual emissions (Mt) in Morocco. All the data used in this study were extracted from the World Bank's online database.

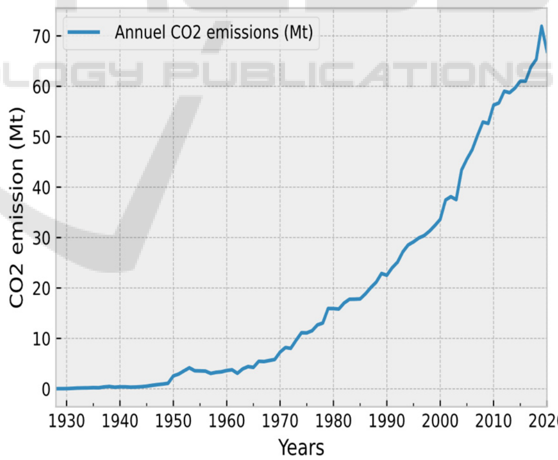


Figure 1: The annual $CO_2$ emissions in Morocco for the period 1928-2020.

We note that our series is not stationary, as shown by an upward trend over the period 1928- 2020. This indicates that the mean and variance of annual $CO_2$ emissions change over time. In addition, carbon dioxide emissions in 2020 dropped by 7% in 2020, the most significant decrease on record, as countries worldwide, imposed lockdowns and restrictions on movement to curb the spread of the coronavirus pandemic (IEA, 2021).

## 4.1 The ADF Test for Stationarity

After applying Augmented Dickey–Fuller test on our series, we found that the ADF value is 3.713814, which is superior to the critical value of significance level of 10%, 5% and 1%, respectively. Hence, it cannot reject the presence of the unit root. Based on the unit root test, the $CO_2$ emission series in Morocco seems to contain a unit root. Indeed, our series is non-stationery. Indeed, the ADF value at the first difference is -8.915777, which is below the critical value of the significance level of 10%, 5% and 1%, respectively. It is stationary at the 1st difference (Jamii and Maaroufi, 2021). The specific results are provided in Table 1.

Table1: Augmented Dickey–Fuller test

| Test critical values (%) | Unit Root Test (Level) | | Unit Root Test (First diff) | |
|---|---|---|---|---|
| | T Statistic | Prob | T Statistic | Prob |
| | 3.713814 | 1.00 | -8.91577 | 0.00 |
| 1 | -3.513 | | -3.532 | |
| 5 | -2.897 | | -2.906 | |
| 10 | -2.586 | | -2.590 | |

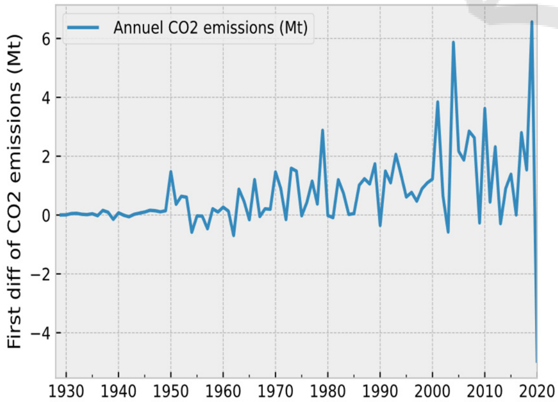


Figure 2: The time series plot of the first difference of $CO_2$ emissions of Morocco

The next step is to simulate the procedure for the $CO_2$ emissions series. We start by using the correlogram of the stationary series, and we can obtain from (Fig 3 and Fig 4) the results of the correlation analysis. From the autocorrelation coefficients and partial autocorrelation coefficients, we attempt to adjust a random time series.

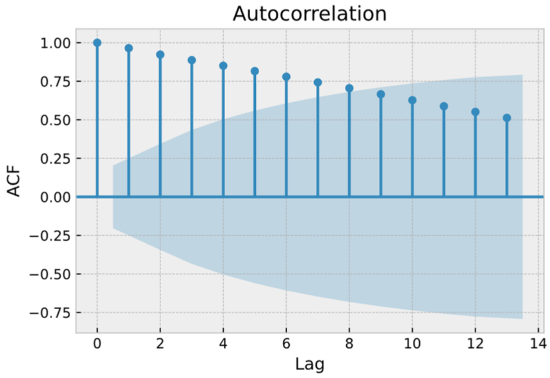


Figure 3: The first-order autocorrelation coefficients of carbon dioxide emissions

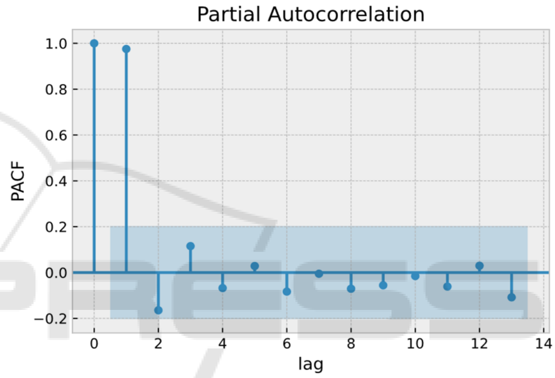


Figure 4: The first-order partial autocorrelation coefficients of carbon dioxide emissions

## 4.2 Evaluation of ARIMA Models

Table 2: overview of information criteria

| Model | AIC | BIC | HQIC | Log Likelihood |
|---|---|---|---|---|
| ARIMA (1,1,1) | 318.430 | 325.995 | 321.483 | –156.215 |
| ARIMA (1,1,2) | 306.486 | 316.933 | 310.917 | –149.423 |
| ARIMA **(2,1,1)** | 305.739* | 315.739* | 309.727* | –148.826* |
| ARIMA (2,1,2) | 307.198 | 319.807 | 312.287 | –148.599 |
| ARIMA (3,1,1) | 307.130 | 319.739 | 312.219 | –148.565 |

In order to obtain the best ARIMA, we applied selection criteria such as log-likelihood, AIC (Akaike information criterion), BIC (Bayesian information criterion) and HQC (Hannan Quinn information criterion). The ARIMA (2, 1, 1) model is chosen as the optimal model due to the lowest value of AIC, BIC and HQC and the maximum value of Log-Likelihood as shown in Table 2.

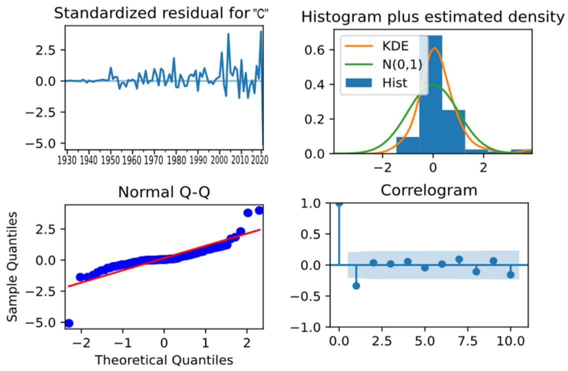


Figure 5: Residuals diagnostic plots of ARIMA (2,1,1)

# 5 RESULTS & DISCUSSION

## 5.1 Descriptive Statistics

We notice from the table below that Jarque-Bera (JB = 454) indicates a critical probability of 0.52. We accept H0 of normality of residuals. Therefore, Homoscedasticity residues are verified. Residues are white noise processes.

Table 3: Descriptive Statistic from ARIMA Model

| Mean | Std | Skew | Kurtosis | JB | Prob |
|---|---|---|---|---|---|
| 19.15 | 21.09 | 0.58 | 8.70 | 454 | 0.52 |

## 5.2 Estimation of ARIMA (2,1,1)

The parameters of ARIMA (2,1,1) are listed in table 3. Thus, the forecasted model can be written as follows:

$$Y_t = 0.4956Y_{t-1} + 0.4937Y_{t-2} - 0.8475\mathcal{E}_{t-1} + \mathcal{E}_t \qquad (6)$$

Table 4: ARIMA (2, 1, 1) Final parameter estimates

| Variable | Coef | Std err | Z | Pb |
|---|---|---|---|---|
| AR (1) | 0.4956 | 0.075 | 6.583 | 0.000 |
| AR (2) | 0.4937 | 0.076 | 6.483 | 0.000 |
| MA (1) | -0.8475 | 0.085 | -10.006 | 0.000 |

A comparison between the actual data obtained from the dataset and the predicted data based on the ARIMA model is presented in Fig. 6. It can be seen that the two graphs match well. The predicted data follow the shape of the data graph. This shows the extent of convergence of the model estimated from the real data.

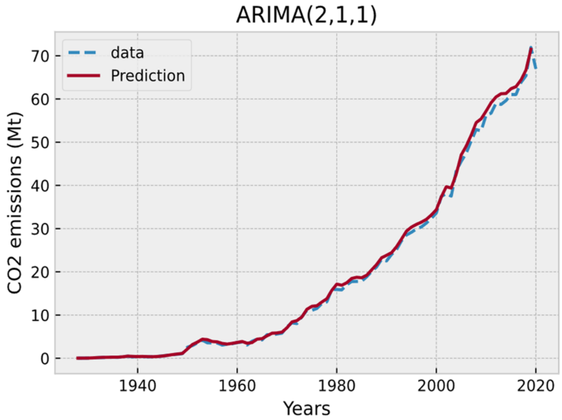


Figure 6: Actual, fitted plot of $CO_2$emission from model selected ARIMA (2,1,1)

## 5.3 Forecast Graph

Based on the estimated model, $CO_2$ emissions are provided over the next two decades. The results in Figure 7 show that by 2040, annual CO2 emissions will continue to increase from 69.18 million tonnes of carbon dioxide equivalent to 109.25 million tonnes of carbon dioxide equivalent. However, this increase is due to the growth of the Moroccan population in recent years, and consequently, the need for electricity is increasing. Indeed, the main sources of carbon dioxide emissions in Morocco are electricity generation and transport sector. According to the latest statistics, in 2016, the electricity sector generated 39% and the transport sector 31% of total emissions. The rest came from industry (13%), residential and commercial buildings (12%) and agriculture (5%). (International Energy Agency, 2019).

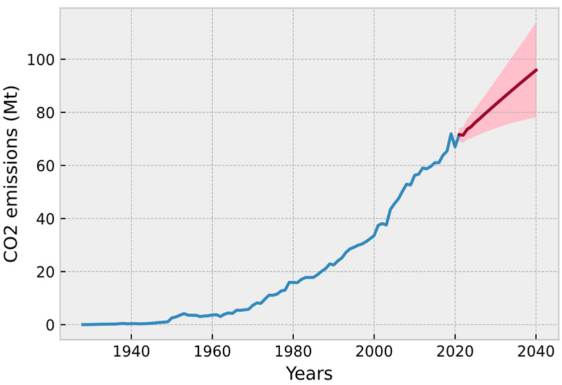


Figure 7: Forecast of $CO_2$ emissions over the next two decades (2021 to 2040)

### 5.4 Policy Implications

In this paper, we have discussed the forecasting of $CO_2$ emissions in Morocco based on the Jenkins approach (ARIMA). The results show that the ARIMA method performs well in predicting $CO_2$ emissions for the next 20 years and offers increased $CO_2$ emissions. These results are essential for the Moroccan government. This knowledge can be used in the decision-making process, such as energy control in the transport sector. Some recommendations can be listed as follows:

- Support the integration of renewable energy sources in homes for householder self-consumption.
-The adoption of electric cars is also highly recommended, as it will decrease the transport sector's emissions, especially if the energy needed to run them is produced by renewable sources.
-Allowing discounts on the purchase of low consumption and environmentally friendly household appliances.
-Initiate policy actions such as increasing taxes on the polluting companies, particularly those that burn fossil fuels in their daily production activities.

## 6 CONCLUSIONS

In this study, we developed an ARIMA model to forecast $CO_2$ emissions in Morocco using the Box-Jenkins time series approach. The historical $CO_2$ emissions data have been used to develop several models, and the appropriate model selected based on four performance criteria: AIC, BIC, HQIC, and maximum likelihood. As a result, we found that the ARIMA (2,1,1) model is the model that minimizes the four previous criteria. The results obtained prove that this model can be used to model and forecast future $CO_2$ emissions over the next two decades in Morocco.

The results of this study are vital as they can be used by researchers, stakeholders and, the Moroccan government to take adequate measures to implement a sustainable climate policy. In addition, an accurate forecast of $CO_2$ emissions on our territory will help the country's political leaders to negotiate a climate fund with the international community.

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