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THE SUITABLE FORECASTING MODEL FOR THE CARBON DIOXIDE EMISSION IN SRI LANKA

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Abstract

Forecasting is used to predict future trends and changes. It is a significant way to analysis of sustainable future movements. An only a limited number of studies have been carried out on the topic of forecasting the carbon dioxide emissions in Sri Lanka. This paper aimed to find a more suitable forecasting model among the linear trend model, growth curve model, quadratic trend model, and s-curve trend model. Variable of carbon dioxide emission based on the data from 1970 to 2019. The findings were explained the quadratic trend model is a more suitable and efficient forecast model for the CO_2 in Sri Lanka. The findings are based on Mean Absolute Percentage Error and Adjusted R^2. The researcher should explore other models to obtain the result in their future studies.

Keywords: CO_2, Forecasting, Curve fitting, MAPE

1. Introduction

Carbon dioxide emissions are one of the primary environmental concerns and a key contributor to global warming. The CO_2 emissions are produced by the combustion of fossil fuels and the production of cement. Carbon dioxide is produced as a result of the combustion of solid, liquid, and gas fuels, as well as gas flaring. (www.knoema.com). Auffhammer and Richard (2008) said that the CO_2 forecast is not just a prediction; it also predicts the expected benefits and costs of reducing global warming. Less environmental impact and low carbon emission are the key characteristics to concern for the business sustainability (Gamage, 2014).

Sri Lanka is a developing country. Its economy is based mostly on agriculture and less on industry. Manuela (2017) had written Agriculture process generates 14%, and the industrial revolution was generating 3% greenhouse gases while the energy industry generates high levels of CO_2. Commonly carbon emission was increased from 3.1 million tons in 1970 to 27.6 million tons in 2019, growing at an average annual rate of 5.06% in Sri Lanka (www.knoema.com). It is a problem of the statement of this examination. The main objective of this paper, examine the suitable model for the forecast to CO_2 among the consider 4 models. It will help to address the future condition of the CO_2 and will able to make the policy to the issue regarding that.

2. Literature Review

Siqi Xu et al. (2020) was studied carbon emission prediction with a dynamic model averaging approach. At the end of the result, he was found, the dynamic model averaging method is the most suitable forecast of carbon emission in China compared to other models. Yao Qian et al. (2020) was an analysis of CO_2 drivers and emissions forecast in a typical

industry-oriented country: changing country, China. The result is shows; the STIRPAT model predicted that energy structure would be the conclusive factor constrictive total CO_2 emissions from 2018 to 2035.

One study has been conducted that expands the literature on the prediction of carbon dioxide emissions using the reduced form econometrics approach of Schmelanci et al. (2017). Based on the analyst's parameter estimates, it is planned to reduce emissions by 25% by 2050, depending on the economic and demographic growth scenario. Saleh (2015) suggested a support vector machine for predicting expenditure of carbon emission and measuring the error of the model by using Root Mean Square Error.

3. Materials and Methods

Basically, forecasting models are classified as qualitative and quantitative. The quantitative model is divided into causal and time series. The special category of time series has several methods. There are naive, simple average, simple moving average, weighted moving average, exponential smoothing, trend adjust exponential smoothing, adaptive response rate exponential smoothing, ARIMA, and curve fitting.

Curve fitting technique that attempts to explain variation using statistical tools. This analysis considers only four types of models under the curve fitting method for getting suitable models to providing future best estimations.

Liner Trend Model

[1] $$Y_t = \alpha + \beta t + \varepsilon$$

Growth Curve Model

[2] $$Y_t = \alpha\beta^t + \varepsilon$$

Quadratic Trend Model

[3] $$Y_t = \alpha + \beta_1 t + \beta_2 t^2 + \varepsilon$$

S-Curve Trend Model

[4] $$Y_t = \frac{A}{\alpha+\beta\gamma^t} + \varepsilon$$

Carbon dioxide emission (Tons of CO_2 per capita) data from 1970 - 2019 data were collected from www.knoema.com. It was yearly data. There were used for model fitting. The software of Minitab 17 was used for the analysis. The residual was examining the goodness of model fit.

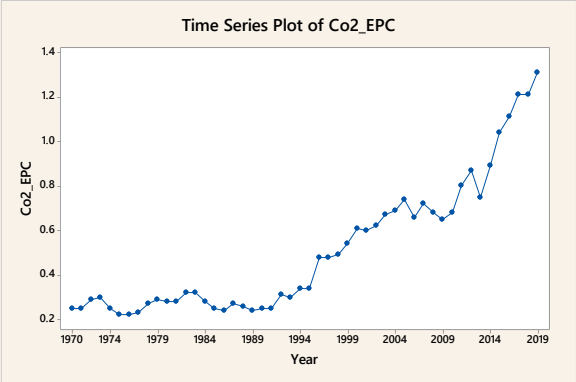
At the same time, the Durbin Watson test and the Anderson Darling test were used to test the auto correlation of residuals and the normality of residuals, respectively. The forecasting capability of the models was measured by Adjusted R^2 and Mean Absolute Percentage Error (MAPE). The smallest MAPE will represent a more accurate prediction.

[5] $$MAPE = \frac{1}{n}\sum\left|\frac{Y_t - F_t}{Y_t} \times 100\right|$$

MAPE is a good method in evaluating the accuracy of a prediction (McKenzie, 2011). Makridakis (1993) also said that the MAPE is asymmetric in that “equal errors above the actual value result in a greater Absolute Percentage Error than those below the actual value”. The smallest MAPE will represent a more accurate prediction. It is on this basis that the appropriate model is selected. Konarasinghe (2015) take low MAPE value of model among other models to the final prediction.

3. Result and Discussion

Fig.1 Carbon dioxide emission of Sri Lanka (Tons of CO_2 per capita – CO_2_EPC) between 1970 – 2019



The data set of carbon dioxide emission has two faces. There is straight volatility from 1970 to 1995 generally after the 1995 CO_2 was increased. Because Sri Lanka is moving past to the industrialized, we can say that the carbon emission of Sri Lanka does not show any trend from 1970 to 1995 and shows a declining trend from later.

Liner trend model, Growth curve model, Quadratic Trend Model, and S-curve trend models (Pearl-Reed Logistic trend model) also were tested one by one. These figs are clearly showing the actual and fits values.

Fig.2 Linear Trend Model of CO_2

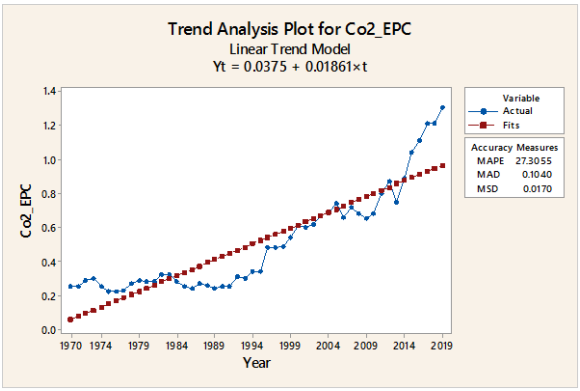


Fig.3 Growth Curve Model of CO_2

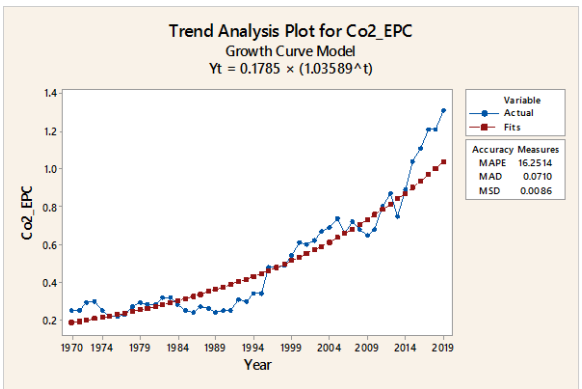


Fig.4 Quadratic Trend Model of CO_2

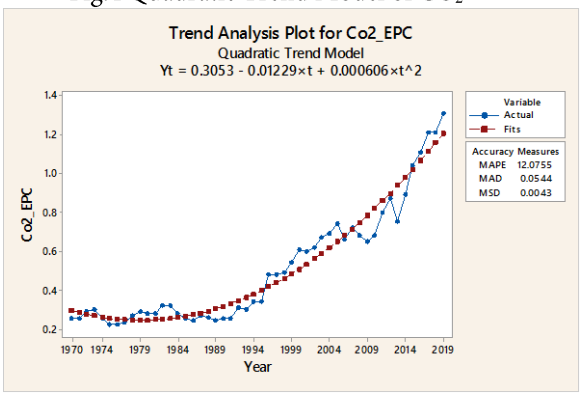


Fig.5 S-Curve Trend Model of CO_2

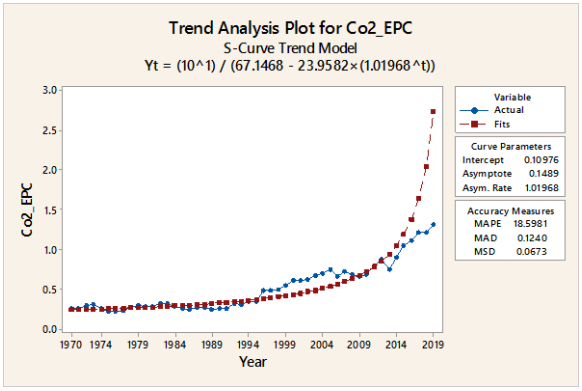
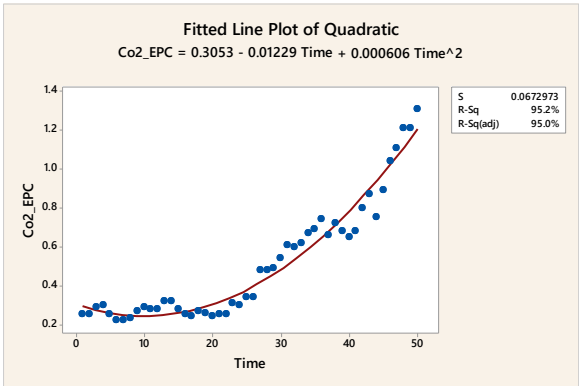


Table 1: Summary of Trend Analysis plots

Trend Analysis Plot	MAPE in Model Fitting
Linear Trend Model	27.3055
Growth Curve Model	16.2514
Quadratic Trend Model	12.0755
S-Curve Trend Model	18.5981

Among the all models, Quadratic Trend Model has law MAPE (12.0755) in model fitting compare with other models.

Fig.6 Fitted Line Plot of Quadratic Model



The adjusted R^2 of the model was 95% and R^2 value is 95.2. The adjusted R^2 should be less than R^2 value. Here it is good.

Fig.7 Residual Plot

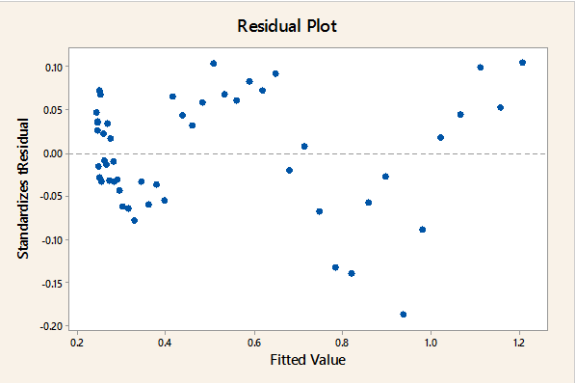
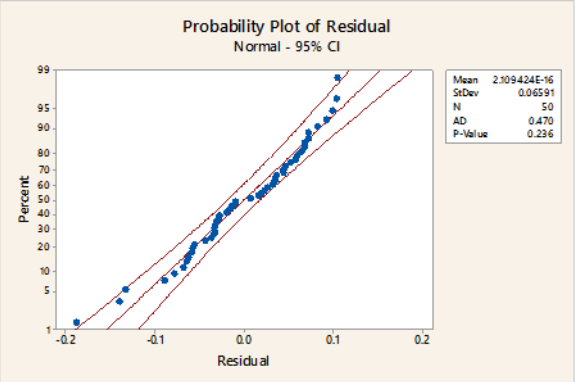


Fig.8 Probability Plot of Residual



Normality of residuals and serial correlations of residuals of the Quadratic model was also tested. Residuals were scattered above and below zero but not consistently distributed. It means autocorrelation of residuals exist

According to the Anderson Darling test, we can analyze the residual.

$\boldsymbol{H_0}$**:** The residuals are normally distributed

$\boldsymbol{H_1}$ **:** The residuals are not normally distributed

Here, the P value (0.236) is greater than the 5% significant or 95% confident level. So, we reject the alternative hypothesis. Therefore, we conclude the residuals are normally distributed.

Finally, the Quadratic model has a low MAPE value and high adjusted R^2, we concluded that the best fitting model for forecasting carbon emission in Sri Lanka.

[6] $$Y_t = 0.3053 - 0.01229t + 0.000606t^2$$

9. Conclusion

According to the four models of the analysis, the suitable model is the Quadratic trending model. It has low MAPE, high R^2, and also residuals are normally distributed. Therefore, we say it's an efficient forecasting model for carbon emission in Sri Lanka. Future researchers within this area should include Auto-Regressive models, Moving Average models, or Auto-Regressive Moving Average models for analysis and provide results.

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