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Multilayer Perceptron Artificial Neural Network Model for Predicting Carbon dioxide Emissions in Malaysia as A Function of Economic and Energy Indicators

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Abstract
Purpose: This study was aimed to investigate the non-linear relationship between economic indicators, energy indicators, and carbon dioxide emission in Malaysia using Artificial Neural Network Predictive Modeling technique.
Design/methodology/approach: The study employed Artificial Neural Network modelling technique to develop a predictive model for carbon dioxide emission in Malaysia. Multilayer perceptron and Levenberg-Marquardt training algorithm were employed for the neural network architecture and the training algorithm, respectively.
Findings: The study revealed that a non-linear relationship exists between economic indicator, energy indicators and carbon dioxide emission. Based on this existing relationship, an ANN model with architecture of 5, 14, 1 for the input layers, hidden neuron and the output layer, respectively was developed to predict the carbon dioxide emission. The predicted carbon dioxide was in good agreement with the actual values indicated by the R^2 of 0.999.
Research limitations/implications: The data employed in this study is limited to Malaysia scenario and cannot be generalised and applied to other countries scenario.
Practical implications: The findings from this study can aid policy formulation by the stakeholders in the energy sector and government towards taking appropriate measures to reducing the carbon dioxide emission in the future.
Originality/value: To the best of our knowledge, there are no studies in literature that employed artificial neural network for predictive modelling of carbon dioxide emission in Malaysia based on the relationship between the economic indicators, energy indicator and carbon dioxide emission.
Paper type: Research paper

Keywords: Predictive modelling, Economic indicators, Carbon dioxide, Gross domestic product, Electricity generation

Introduction

Economic and social development is often driven by the activities in the energy sector (Fankhauser & Jotzo, 2018). Over the years, there have been an increase in the energy consumption as the population increases (Dong et al., 2018). Moreover, economic growth has been reported to increase with corresponding increase in energy consumption (Cai et al., 2018). Malaysia has witness strong population growth and rapid economic growth which can be inferred to be responsible for the high energy consumption over the last 30 years as shown in Figure 1. To meet the growing energy consumption in Malaysia, the energy generation has been highly carbonised as a result of over dependent on fossil sources such as coal and natural gas (Islam et al., 2019). Studies have shown that 8.13 metric tons of carbon dioxide emission per capita was recorded in Malaysia in 2014 and has been projected to increase at an annual rate of 3.09% (The World Bank Group, 2021) Basically, energy generation industries and the transport sector which are highly carbonised are responsible for the larger share of the amount of carbon dioxide emission annually. This study focuses on investigating the interlink between energy indicators, economic indicators and CO_2 emissions in Malaysia using Artificial Neural Network modelling techniques. Furthermore, using the derived relationship by the ANN model, a predictive trend of the CO_2 emissions in Malaysia was formulated.

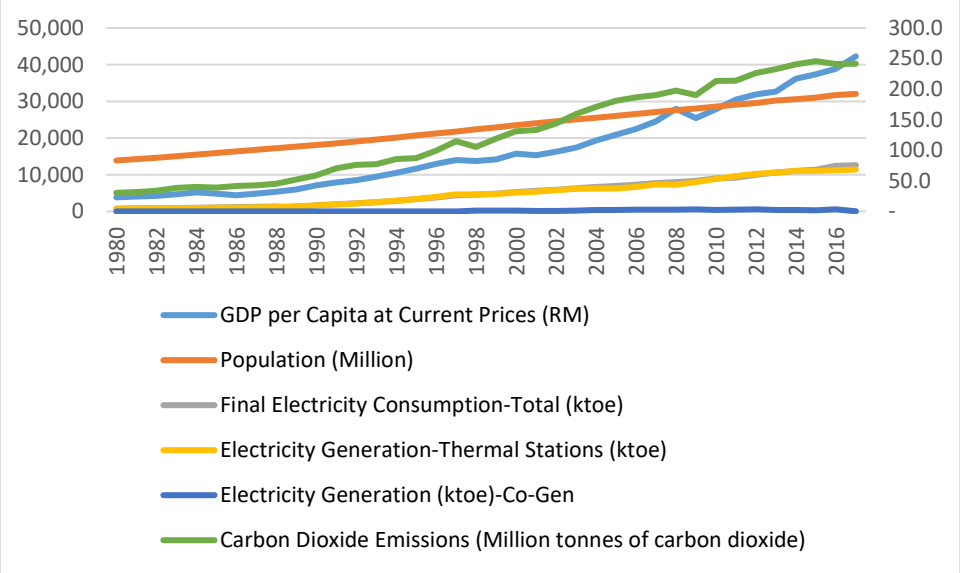

Figure 1: Trend Showing GDP per Capital, Population, Final Electricity Consumption, Electricity Generation (Thermal Station), Electricity Generation (Co-Gen), and CO_2 Emissions from 1990-2016 in Malaysia

Literature Review

Greenhouse effect which is the sole causes of climate change is often caused by actions of emitted greenhouse gases and as CO_2 from the anthropogenic human activities (Ayodele et al., 2016). This phenomenon has created the curiosity to investigate the relationship between energy indicators, economic indicators and CO_2 emissions around the world. CO_2 emission is often influence by several factors such as energy consumptions mostly from fossil sources, energy generation from fossil sources and other economic related activities (Mardani et al., 2018; Arouri et al., 2012). Series of studies have been conducted to investigate the interlink

between energy intensity, energy consumptions, GDP and CO_2 emissions using parametric and empirical approaches (Al-Mulali & Che Sab, 2018; Mikayilov et al., 2018; Mustapa et al., 2020). The findings from these studies revealed that there was a direct relationship between energy indicators, economic growth and CO_2 emissions as supported by Saboori, Sulaiman, & Mohd (2012).

Methods

Artificial neural network modeling technique which mimic the human neuron was employed in this study (Hossain et al., 2016). The ANN configuration shown in Figure 2 consists of the input layer, the hidden layer and the output layer. The input parameters are made of the economic indicators which consists of GDP per capita, and population as well as energy indicators which consist of final electricity consumption, electricity generation by thermal stations and electricity generated by co-generation. The output layer is the carbon dioxide emission. The data used for the modeling were obtained from the Malaysia Energy Information Hub online database which span from 1980-2017 (Suruhanjaya Tenaga, 2011). The ANN predictive modeling was done using MATLAB version 2019a (MathWorks Inc., Natick, MA, USA). Levenberg-Marquardt algorithm was employed for training the data prior to the configuration of the network. An optimised hidden neuron of 14 was used for the network architecture.

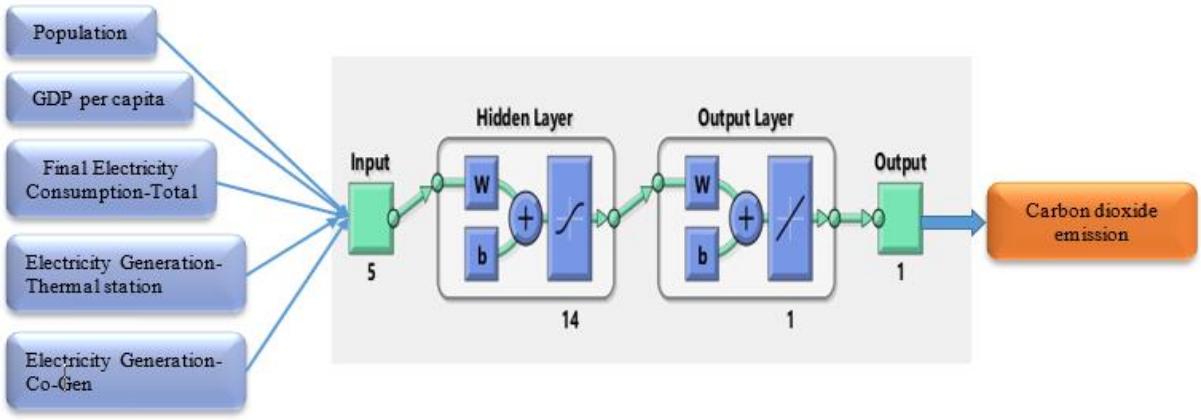

Figure 2: Artificial Neural Network Configurations for the Predictive Modelling of Carbon Dioxide Emissions in Malaysia

Results and Discussion

Figure 3 shows the three-dimensional plots of the relationship between the economic indicator, energy indicator and the carbon dioxide emission. It can be seen that carbon dioxide emission in Malaysia between 1980 and 2017 is strongly dependent on the electricity generation, electricity consumption, GDP per capita and the population growth. Several studies have supported the interlink between economic indicator, energy indicator and carbon dioxide emissions. Mardani, Streimikiene, Cavallaro, Loganathan, & Khoshnoudi (2019) established that increase in economic growth often results in a corresponding increase in energy consumption which must be met by generating more energy. Since Malaysia energy generation is highly carbonised, there has been a corresponding increase in the amount of carbon dioxide emission over the years. There is a consensus in literature regarding the existence of unidirectional causality from energy use to economic growth. This study is also in agreement with the work of Meng, Crijns-Graus, Worrell, and Huang (2018) who reported the impact of booming economic growth and urbanisation on carbon dioxide emissions in Chinese metropolises from 1985-2010 using index decomposing analysis. The study revealed that the

rise in economic growth and expanding urban areas were the major drivers of carbon dioxide emission in Chinese metropolis from 1985-2010. Bekun, Emir and Sarkodie (2019) also concur that there is an interrelationship between energy consumption, economic growth and carbon dioxide emission within the context of South Africa. The empirical evidenced by the authors indicates a one-way causality from energy use to economy growth.

The comparison between the ANN predicted carbon dioxide emission based on the relationship between the economic indicators, energy indicators and carbon dioxide are represented in Figure 4. It can be seen in Figure 4 (a) that the ANN predicted carbon dioxide emission is in proximity with the actual values of the carbon dioxide emission. This is an indication that the ANN model is a very robust in learning the non-linear relationship between the economic indicators, energy indicators and the carbon dioxide emission (Mardani et al., 2020). The robustness of ANN as predictive modeling techniques has been reported in several studies (Mohandes, Zhang, & Mahdiyar, 2019; Ayodele et al., 2021). The parity plot showing the comparison between the predictive carbon dioxide emissions by the ANN and the actual values is depicted in Figure 4 (b). The coefficient of determination (R^2) of 0.99 obtained shows that there is strong correlation between the predicted carbon dioxide and actual values.

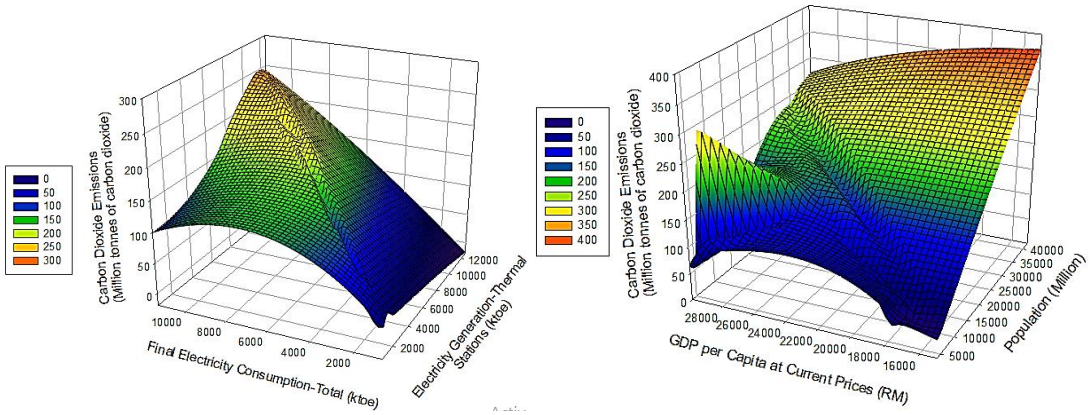

Figure 3: Three Dimensional Plots Showing the Relationship between (a) Energy Indicator (b) Economic Indicator and Carbon Dioxide Emission

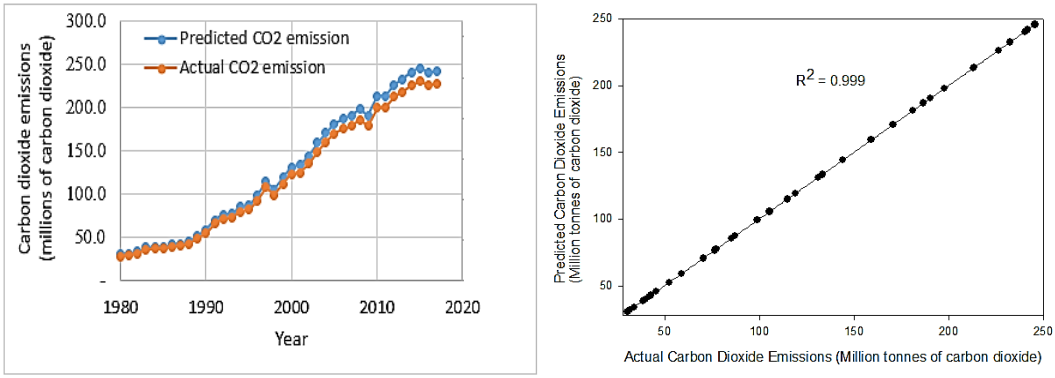

Figure 4: (a) Trend of the ANN Predicted and the Actual Values of Carbon Emission (b) Parity Plot Showing the ANN Predicted and Actual Value of Carbon Emission

Conclusion

This study has demonstrated the use of artificial neural network for the predictive modeling of CO_2 emission in Malaysia based on the relationship between economic indicator, energy indicator as well as CO_2 emission. Historical data from 1980 to 2017 were employed for the ANN modelling using Levenberg-Marquardt training algorithm. The ANN modelling shows

that there is an interlink between economic indicator, energy indicator and CO_2 emission in Malaysia. The predicted CO_2 emissions is agreement with the actual values. Using both the economic and the energy indicators, necessary measures can be mapped by the stakeholders to drastically reduce the CO_2 emissions over time in Malaysia.

Theoretical Implications

There are no studies in literature that employed artificial neural network for predictive modelling of carbon dioxide emission in Malaysia based on the relationship between the economic indicators, energy indicator and carbon dioxide emission.

Practical and Social Implications

It is expedient for all the necessary stakeholders and policy makers in Malaysia to evaluate the extent of energy utilisation using the appropriate indicators in order to determine its immediate and long-term effects on the environment.

Limitations and Suggestions for Future Research

Moreover, based on the energy and economic projections, there is a need to critically determine what needs improvements in order to drastically reduce the amount of CO_2 emitted in the future. The consequences of chosen an energy and economic programs on the environment in terms of CO_2 emission must be critically examined.

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