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Prediction of GDP growth rate based on carbon dioxide (CO2) emissions

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ABSTRACT

The environment that governs the relationships between carbon dioxide (CO2) emissions and gross domestic product (GDP) changes over time due to variations in economic growth, regulatory policy and technology. The relationship between economic growth and carbon dioxide emissions is considered as one of the most important empirical relationships. However, rigorous economic causal analysis of the tradeoff between carbon dioxide (CO2) emissions and economic growth for credible climate change policies is still limited. The purpose of this research is to develop and apply the Extreme Learning Machine (ELM) to predict GDP based on CO2 emissions. The ELM results are compared with genetic programming (GP) and artificial neural network (ANN). The reliability of the computational models was accessed based on simulation results and using several statistical indicators. Coefficients of determination for ELM, ANN and GP methods were 0.9271, 0.8756 and 0.4475, respectively. Based upon simulation results, it is demonstrated that ELM can be utilized effectively in applications of GDP forecasting.

1. Introduction

Over the past two decades, the menace of climate change due to increased global warming has been a major environmental challenge. Rising levels of carbon dioxide emissions is considered one of the principal causes of global warming and climatic instability. In this regard, one of the most important issues in energy economics literature is mainly focused on testing the relationship between economic growth and carbon dioxide emissions.

The CO2 emission is directly linked to the economic growth, which is an important factor in the economy of the world both for production and consumption. Also most of the CO2 emissions come from gaseous/liquid/solid fuel consumption, which is an essential source of the automobile and industry that are closely related to the economic development and economic growth. Therefore the inseparable relationship between the CO2 emissions and economic growth acts as an important bridge between the economic and environmental policy.

Indeed, the increase of the CO2 emissions is a major threat of to the climate change which is the major on-going concern of both the developing countries to developed countries. The economic growth of the developed countries impels an intensive use of energy and as a result, more residues and wastes are throw nature that could lead to environmental degradation. A CO2 emission is regarded as the main source of the greenhouse effect and has captured great attention in the recent years. Most of the CO2 emissions come from the fossil fuels consumption such as coal, the main power source of the automobile industry that is directly linked with economic growth and development. The direction of causality between economic growth, electricity consumption and CO2 emissions is important for the implementation of related policies. If, for example, electricity consumption causes economic growth, the country would have to implement expansive energy policies.

In the last three decades, the effects of CO2 emissions on economic growth have become a topic very significant both at the national and international level. On the other hand, there are a number of studies considering the inseparable relationship between the CO2 emission and economic growth in recent years. In study [1] was confirmed a long-run relationship between CO2 emissions and economic growth. A quantitative structural modelling perspective and policy analysis from an economic integration framework and system estimation on the growth-CO2 emission causality nexus in general and on a major developing country in Asia was presented in [2]. The results in study [3] were shown that there is a nonlinear relationship among CO2 emissions per capita, energy consumption per capita, and gross domestic

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product (GDP) per capita. Empirical relationship between economic growth, energy consumption and carbon dioxide emissions was examined in [4], was calculated the trend of decoupling effects and finally analyzes the evolution of inequality in CO2 emissions. In article [5] was investigate the causality links between CO2 emissions, foreign direct investment, and economic growth using dynamic simultaneous-equation panel data models and results provided evidence of bidirectional causality between FDI inflows and economic growth for all the panels and between foreign direct investment and CO2 emissions. A network of causal connections among extent of urbanization, CO2 emissions, and economic growth in the short run was sound in [6]. Dynamic relationship between economic growth and carbon dioxide (CO2) emissions was investigated in [7] for 181 countries and it was found that for 49 countries (27%), income growth will reduce emissions in the future. Dynamic impacts of GDP growth, energy consumption and population growth on CO2 emissions using econometric approaches for Malaysia was investigated in [8]. The impact of energy consumption and the CO2 emissions on economic growth using simultaneous-equation models with panel data for 58 countries over the period 1990–2012 was evaluated in [9] and the empirical results were shown that energy consumption has a positive impact on economic growth. A bidirectional time-varying causality between energy consumption and CO2 emissions was shown in [10,11]. To evaluate the dynamic behaviors of the energy consumption and CO2 emissions, a few of interdisciplinary studies have been conducted [12–14].

Even though a number of new mathematical functions have been proposed for modelling of the GDP growth rate prediction based on the CO2 emissions, in this investigation the main aim is to overcome high nonlinearity by applying the soft computing method. Soft computing can be used as alternative to analytical approach as soft computing offers advantages such as no required knowledge of internal system parameters, compact solution for multi-variable problems.

Recently, the Extreme Learning Machine (ELM) has been introduced as a soft computing algorithm for single layer feed forward neural network (NN) [15,16]. It is capable to solve problems caused by gradient descent based algorithms like back propagation which applies in artificial neural networks (ANNs) and to decrease required time for training NN. It has been proved that by utilizing the ELM, learning becomes very fast and it produces good generalization performance [17]. It has been widely utilized for the estimation of problems in many different fields of water resources [18–20].

In this investigation the main goal is to anticipate GDP by using ELM approach. The primary objective is to analyse the CO2 emission forecasting based on the CO2 emissions from gaseous/liquid/solid fuel consumption.

2. Methodology

2.1. Statistical data and study area

Currently, the increased greenhouse gas concentrations in the atmosphere are one of the most pressing environmental problems. CO2 is an important green-house gas and a major driver of climate change effects, as a result the predicted global temperature rise will be proportional to the total amount of CO2 emitted. In recent years, increases in carbon dioxide concentrations are mostly due to rapidly increasing population energy use, and emissions from vehicular traffic. In fact, half of the world's population is living in cities and in Europe alone, it is estimated that around 70% of the EU population – approximately 350 million people live in urban agglomerations of more than 5000 inhabitants. Therefore in this study the main aim is to CO2 emission from different sources influence on the economic growth in European Union.

Table 1
Input and output parameters.

Inputs	Parameters description
input 1	CO2 emissions from gaseous fuel consumption (% of total)
input 2	CO2 emissions from liquid fuel consumption (% of total)
input 3	CO2 emissions from solid fuel consumption (% of total)
output	Real GDP growth rate

Table 1 shows inputs and output parameters which were used in this study. The dataset was taken from World Bank database for European Union countries. CO2 emission is analyzed for gaseous, liquid and solid fuel consumption. As the output real GDP growth rate was used.

2.2. Extreme learning machine

Huang et al. [21,22] developed Extreme Learning Machine (ELM) as a learning algorithm for single hidden layer feed forward networks (SLFNs). This approach has some priority compared with conventional neural networks including:

1. ELM is easy to use, and it method increase not only makes learning extremely fast but also produces good generalization performance [21,22];
2. In conventional neural networks all the parameters of the networks such as learning rate, learning epochs and local minima are tuned iteratively by using such learning algorithms;
3. ELM can be easily implemented and can obtain the smallest training error and the smallest norm of weights [21,22].

Fig. 1 depicts the flow chart for the ELM prediction of GDP. The average computation time for the ELM modelling was around 330 s using a PC with the Intel Core Duo CPU E7600 and 2-GB RAM.

2.3. Models performance evaluation

Predictive performances of the proposed models were presented as the root means square error (RMSE) and coefficient of determination (R^2). These statistics are defined as follows:

1) Root-mean-square error (RMSE),

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}, \quad (1)$$

2) Coefficient of determination (R^2)

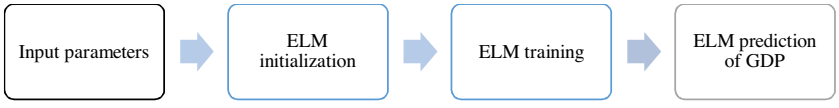

Fig. 1. Flow chart of proposed ELM approach for the GDP prediction.