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Using Grey Models for Forecasting Vietnam's Carbon Dioxide Emissions in Renewable Energy Consumption and Economic Growth Trends

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Abstract: ***This paper analyzes and forecasts of carbon dioxide (CO_2) emissions, renewable energy consumption, and gross domestic product (GDP) for Vietnam during the period of 2010 to 2019. These three variables are important factors that affect the energy efficiency, economic growth as well as climate change in Vietnam. Thus, this paper employs the grey prediction models including GM (1,1) and DGM (1,1) to predict three variables. According to forecasting results, the CO_2 emissions of Vietnam will grow by 3 %, the renewable energy consumption is not increase significantly, and the GDP is forecasted to increase 5% in 2019 compared with 2010. The study provides policy makers with useful information in finding the solutions to improve energy efficiency, economic growth and environmental protection in Vietnam.***

Keywords: ***CO_2 Emissions, Renewable Energy Consumption, Economic Growth, Grey Models.***

I. INTRODUCTION

In recent years, Vietnam's economy is one of the emerge market in Asia, along with it's rapid economic growth, Vietnam's demand for energy consumption also has increased tremendously [1]. However, like other countries in the world, increase in the energy consumption, economic growth as well as carbon dioxide emissions ($CO_{2)}$ are the main cause of environmental pollution in Vietnam [2]. Thus, the study of how to balance between economic growth and environmental protection is an urgent issue of Vietnam and many countries. Renewable energy is relative new in Vietnam. It's is advantage in sustainable development and reduce greenhouse gas emissions [3]-[4]. According to renewable 2017 [5], renewable energy contributed 19.3% to humans' global energy consumption and 24.5% to their generation of electricity in 2015 and 2016, respectively. Hence, research on renewable energy efficiency, CO_2 emissions and economic growth is become significant in climate change mitigation, and economic benefits.

Several studies have indicated the relationship between CO_2 emissions, energy consumption and economic growth [6-10].Xie et al. [11] applied grey forecasting model to forecast energy demand during 2006-2020 in China. The results showed that the growth rate of energy consumption in China has decreased under the energy saving policy. Lin et al. [12] used GM(1,1) model to predict CO_2 emissions in Taiwan. Hamzacebi and Karakurt[13]forecasted the energy-related CO_2 emissions for the period of 1965–2012 in Turkey. The results of this study indicated that the amount of CO_2 emissions will increase of 64% growth in 2025 compared to that in 2010.

As of yes, there has been no study to predict the CO_2 emissions, renewable energy consumption and economic growth in Vietnam. Thus, this study applied grey forecasting models including GM(1,1) model and DGM(1,1) model to forecast the future values of the CO_2 emissions, renewable energy consumption and GDP in Vietnam. The mean relative error has been calculated to evaluate the accuracy of prediction models. The highest precision of predicting model will be implemented to predict the future values.

II. MATH

This section describes two prediction models including GM(1,1) and DGM(1,1). Two models are employed to forecast CO_2 emissions, renewable energy consumption and GDP for Vietnam from 2010 to 2019. The overview of the relevant principles of GM(1,1) and DGM(1,1) are presented as follows:

A. GM (1,1) Grey Forecasting Model:

Grey system theory was designed by Deng [14]. The model of GM(1,1) is one of the most commonly used. GM(1,1) indicates one variable and one order grey forecasting model. GM(1,1) model is conducted as flows:

Establish the initial series to be $X^{(0)}$

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \ldots . x^{(0)}(n)\} \quad (1)$$

Where $X^{(0)}$ is a non-negative sequence and n is the total number of modeling data. From a new data series $X^{(1)}$ by accumulated generating operation (AGO)

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \ldots . x^{(1)}(n)\} \quad (2)$$

Where $X^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \quad k = 1, 2, \ldots, n$

Establish the Grey difference coefficient

$$x^{(0)}k + az^{(1)}(k) = b, k = 2, \ldots, n \quad (3)$$

a is a developing coefficient, b is a control variable.

Thus, the author can calculate the a, b coefficient by the ordinary last squares method.

$$\left[a, b\right]^T = (B^T B)^{-1} B^T Y_N$$

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Where $B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \ldots\ldots\ldots & \ldots \\ -z^{(1)}(n) & 1 \end{bmatrix}$, $Y_N = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \ldots\ldots\ldots \\ x^{(0)}(n) \end{bmatrix}$ (4)

Eq. (3) can be indicated by another type as follows:

$$\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b \quad (5)$$

To solve Eq. 4 and obtain the forecasted values for the data series $X^{(1)}$ from AGO as

$$x^{\wedge(1)}(k+1) = [x^{(0)}(1) - \frac{b}{a}]e^{-ak} + \frac{b}{a}$$

By applying the inverse AGO, the predictions for the original data series can be denoted as:

$$x^{\wedge(0)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right]e^{-ak}(1-e^{a}),$$

Where $k = 2,3,\ldots,n, x^{\wedge(0)}(1) = x^{\wedge(0)}(1) = x^{(0)}(1)$

B. Discrete Grey Model DGM (1,1):

Assume that the sequence

$X^{(0)} = \{x^{(0)}(1), x^{(1)}(2), \ldots\ldots, x^{(1)}(n)\}$, the sequence obtained through accumulating generation, that is:

$x^{(1)}(k) = \sum_{j=1}^{k} x^{(0)}(j),\ k = 1,2,\ldots,n$

The equation:

$$Y = \begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}(n) \end{bmatrix} \quad (6)$$

Is called discrete grey model abbreviated as DGM, use the ordinary least square method to obtain:

$\hat{a} = [a,u]^T = (B^T B)^{-1} BY$

Where $B = \begin{bmatrix} x^{(1)}(1) & 1 \\ x^{(1)}(2) & 1 \\ \vdots & \vdots \\ x^{(1)}(n-1) & 1 \end{bmatrix}, Y = \begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}(n) \end{bmatrix}$

Set $x^{(1)}(1) = x^{(0)}(1)$, the recursive function is given by: $x^{(1)}(k+1) = a^k x^{(0)}(1) + \frac{1-a^k}{1-a}u$

k=1, 2,..,n-1, the restored values of $x^{(0)}(k)$ can be given by:

$$x^{(0)}(k+1) = x^{(1)}(k+1) - x^{(1)}(k) = \left(x^{(0)}(1) - \frac{u}{1-a}\right)\left(1 - \frac{1}{a}\right)a^k,\ k = 1,2,\ldots\ldots,n-1 \quad (7)$$

C. Predictive Accuracy Measurement:

In this study, the author adopted mean relative error (MRE) to measure the accuracy of the forecasting models:

$$MRE = \frac{\sum_{i=1}^{N}\left|\frac{y_i - \hat{y_i}}{y_i}\right|}{N}$$

$\hat{y_i}$ is predicted value by the class *i* prediction model and its actual value is y_i.

III. RESULTS

A. Data Collection:

This study collected annual data on CO_2 emissions, renewable energy consumption and gross domestic product (GDP) of Vietnam from 2010 to 2014. The data was collected from the World bank. CO_2 emissions are those stemming from the burning of fossil fuels and the manufacture of cement. Renewable energy consumption is the share of renewable energy in total final energy consumption. The GDP is calculated in US dollars at 2000 prices [15].

B. Predict and Analysis:

To demonstrate the effectiveness of the proposed grey forecasting models, the real case of CO_2 emissions in Vietnam is considered as an example.

For GM(1,1) model, the original time series x^0 is obtained as $x^0 = [142738,152169,...,166911]$ based on the raw data of CO_2 emissions in Vietnam. We can get the parameters of a and b by the ordinary least squares method. The original GM(1,1) model is expressed as follow:

$a = -0.03365; b = 137298.41$

For DGM(1,1) model, the initialization of raw sequence: $x^0 = [142738,152169,...,166911]$

We can get the parameters of β_1 and β_2 by AGO

$\beta_1 = 1.00332,\ \beta_2 = 140019.93$

In this section, two grey forecasting models including the GM(1,1) and the DGM(1,1) have been contracted to predict value of Vietnam CO_2 emissions, energy consumptions and GDP from 2015 to 2019. The performance of GM(1,1) and DGM(1,1) models presented to compare the forecast accuracy of the above two forecasting models. Then, the best model has been implemented to predict the future value of Vietnam CO_2 emissions, renewable energy consumption and GDP in the next five years. Table 1 shows the predictive values which are calculated by GM(1,1) model and DGM(1,1) model. The results show that the predictive values of two compared models have a strong forecasting

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performance. However, the DGM(1,1) model has small average relative error (1.21%, 0.47% and 0.04%) in 2010-2019 compared with GM (1,1) (4.83%, 1.86%, 0.17%) which means that the DGM (1,1) model is better for forecasting the CO_2 emissions, renewable energy consumption and GDP in Vietnam.

Table 1. Forecasted Values and MRE of CO_2 Emissions, Renewable Energy Consumption and GDP in Vietnam (2010-2019)

	CO_2 Emissions (kt)			Renewable Energy Consumption (% of Total Final Energy Consumption)			GDP (Constant 2010 US$)		
		GM(11)	DGM(11)		GM(11)	DGM(11)		GM(11)	DGM(11)
Year	Actual	Model value	Model value	Actual	Model value	Model value	Actual	Model value	Model value
2010	142,73	142,73	142,73	34,79	34,79	34,79	115,93	115,93	1''\15,93
2011	152,16	144,51	144,75	36,52	37,31	37,31	123,16	122,94	122,94
2012	142,22	149,46	149,56	38,10	37,13	37,13	129,62	129,77	129,77
2013	147,23	154,58	154,53	37,38	36,96	36,96	136,65	136,97	136,97
2014	166,91	159,87	159,66	36,20	36,79	36,79	144,83	144,58	144,58
2015		165,34	164,96		36,63	36,62		152,57	152,61
2016		171,00	170,44		36,47	36,45		161,04	161,09
2017		176,85	176,10		36,30	36,28		169,98	170,038
2018		182,90	181,95		36,14	36,11		179,42	179,48
2019		189,16	188,00		35,98	35,94		189,38	189,44
MRE(%) (2016-2021)		4.83%	1.21%		1.86%	0.47%		0.17%	0.04%

Figure 1-3 show the change trend of each series of CO_2 emissions, energy consumption and GDP in Vietnam. Figure 1-3 present that the CO_2 emissions will reach up to 188,000 kilotons in 2019 with an increase of 3% growth compared to that in 2010. The renewable energy consumption tends to increase 0.33%, and the GDP is forecasted to increase 5% in 2019 compared with 2010.

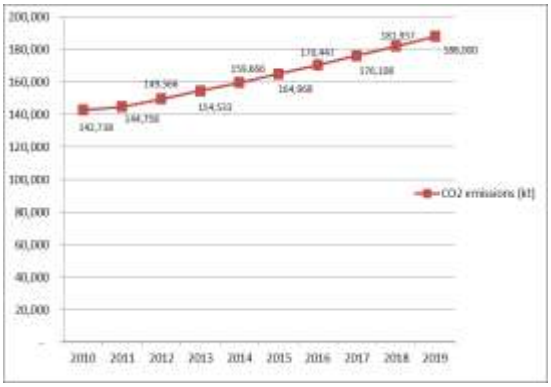

Fig. 1. The Forecasted Data and Actual Data of Vietnam CO_2 Emissions

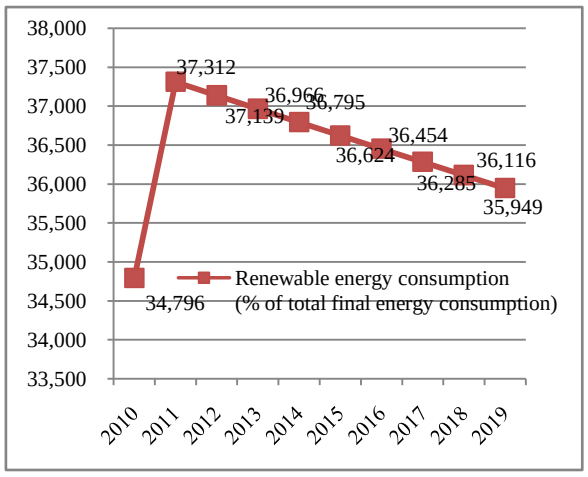

Fig. 2. The Forecasted Data and Actual Data of Vietnam Renewable Energy Consumption

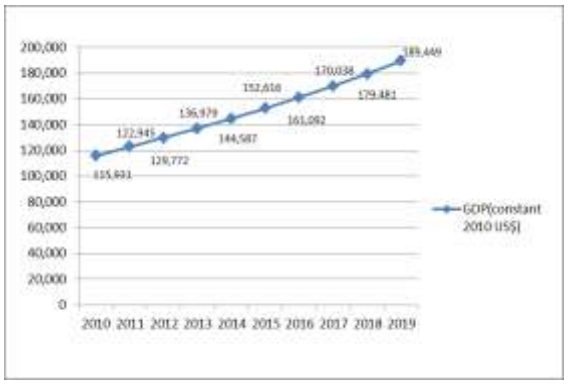

Fig. 3. The Forecasted Data and Actual Data of Viet nam GDP

IV. CONCLUSION

This paper forecasted the CO_2 emissions, renewable energy consumption and GDP in Vietnam by implementing the grey forecasting model GM(1,1) and DGM(1,1) based on the annual data from 2010 to 2014. The results show that the performance of DGM(1,1) model is better than GM(1,1) model. Thus, the DGM(1,1) model has applied to forecast value of the CO_2 emissions, renewable energy consumption and GDP in Vietnam from 2015 to 2019. The predicting values indicated that the GDP of Vietnam will growth to 189,449 million US dollar in 2019, the renewable energy consumption is not increase significantly, the CO_2 emissions will growth to 181, 957(kt) in 2018. This paper provides information to Vietnam policy makers in order to improve renewable energy efficiency, economic growth and reduce CO_2 emissions.

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