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Evaluation of Grey Forecasting Method of Total Domestic Coffee Consumption in Indonesia

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Abstract: Indonesia is the one of the world's top coffee producing and exporting countries. Meanwhile, in this study, only focus on forecasting the total of domestic coffee consumption in Indonesia applied the Grey differential model which is called GM (1,1) model of Grey theory to predict the amount of domestic coffee consumption in Indonesia from 1990 to 2017. According to the estimated result, the average residual error of the Grey forecast model is over 5 percent. The model predicts that the total of consumption will increase in each year. Based on the experimental results, this proposed method apparently not only improve the forecasting accuracy of the original Grey models but also provide a valuable reference for Indonesia coffee farmer and industries to make the action plan for the future.

Keywords: Coffee, Consumption, Forecasting, GM (1,1), Grey Theory, Indonesia

1. Introduction

Indonesia coffee consumption continues to grow currently, driven in part by the marketing strategies and brand awareness [23] efforts. Consumption growth powered by the expansion of retail coffee shops, including franchises and local small business. Coffee outlets target consumers in shopping malls, business centers and public facilities such as airport and trains stations.

According to data from the Association of Indonesian Coffee Exporter and Industries [33], Indonesian farmers together with related ministries plan to expand Indonesian coffee plantations, while rejuvenating old plantations through intensification programs.

By increasing farm area, Indonesian coffee production in the next ten years is targeted to reach between 900 thousand tons to 1.2 million tons per year. Due to the increased global and domestic demand, investment in the country's coffee sector required.

In addition to increasing quantity of coffee beans, quality is also predicted to increase due to technological innovations. Nevertheless, Indonesia's coffee production per hectare is still small compared to the other leading coffee-producing countries.

In 2015, Indonesia produced 741^{kg} of robusta seed per hectare and 808^{kg} of arabica seed per hectare. In Vietnam, this figure reached $1{,}500^{kg}$ per hectare in Brazil reaching $2{,}000^{kg}$ per hectare.

In 2012, approximately 70 percent of the total annual production of Indonesian coffee beans was exported, especially to customers in Japan, South Africa, Western Europe and the United States.

Besides, with total consumption of 3.6 million bags in 2012 [32], Indonesia is the second-largest consumer in the region, from Japan, and the 8^{th} largest in the world. consumption has been increasing quickly, averaging 6.6 percent growth since 2000, and 5 percent per annum going back to 1990.

Meanwhile, with a population of nearly 250 million, per capita consumption is less than 1^{kg} per person, and shows significant potential for further growth. Furthermore, it can assume that the majority of consumption in Indonesia is of

national production, which is 80 percent robusta.

Furthermore, Indonesia also imports around 1 million bags of coffee, predominantly from Vietnam, which further suggests that most consumption is of robusta coffee. domestic consumption as a percentage of total coffee production has increased from an average of 22 percent in the 1990s to around 33 percent over the last five years. If the consumption in Indonesia continues to grow at current rates, the country could reach nearly 6 million bags by 2020, exceeding the current consumption of France [32].

Thereto, as Indonesia's domestic coffee consumption has grown, the number of exports has declined. coffee consumption in Indonesia increased with a compound annual growth rate (CAGR) of 7.7 percent in 2011 to 2014. Still, at 1.0^{kg} (data 2014), coffee per capita consumption remains low in Indonesia.

Whereas, in Asia the total consumption is reasonably high in India, Indonesia and Philippines, although per capita consumption levels are relatively low for instance Asia and the Pacific (estimated) 8.328 such as India 1.800, Indonesia 3.333, Philippines 1.080 and Vietnam 1.583.

Further, consumption of instant coffee mixes and ready-to-drink beverages is also growing. This research collected 27 years data series the total of arabica and robusta coffee for domestic coffee consumption in Indonesia from 1990 to the 2017 [32].

Moreover, to producing regular coffee in Indonesia the farmers produces some specialty coffee. The most famous among these specialty coffees are Luwak coffee, Toraja coffee, Aceh coffee and Mandailing coffee.

The first type of coffee - Luwak coffee - mungking is the most famous coffee type because it is known as the most expensive coffee in the world.

This coffee is extracted from the coffee beans that have been through the Asian civet mongoose digestive system (animals that resemble cats).

Because of the special fermentation process in the animal's stomach (and also because the facts of mongoose can choose the most juicy coffee fruit) this coffee is believed to have a richer taste.

The production process that requires a lot of manpower and scarcity in the international market causes the price to be expensive [34].

On the other hand, a longitudinal study by Deng [3, 4, 5, 6] reported that the first systematic study of Grey theory in 1982, which has been recognized and applied by many academicians in different subjects such as economic prediction [20, 24, 25, 29, 31], material science [11, 12, 14, 15], electrical power [2, 8, 9, 10], traffic [7, 17, 21, 26], technological progress [1, 13, 16], engineering [18, 19] and agriculture [22], chosen Grey prediction as an ability forecasting means because of having relatively low data requirements, and a GM model constructed from a sample of just four pieces of data.

In addition to that forecast method is significant by using the transformed Grey rolling modeling mechanism. This rolling modeling mechanism provides a means to guarantee input data are always the most recent values from time series data to forecast the number to get the result.

The present paper examines the Grey forecasting method of total domestic coffee consumption in Indonesia, during 27 year since 1990 until 2017 and forecast to 2018.

In the first part of the paper a review of literature regarding the existence of Grey forecasting method on different research is presented. It could have been observed that the Grey forecasting method used for several subjects.

Further on, the paper presents the methodology and the data that were used, but also empirical results that were obtained for each observation period. An expression introducing of rolling modeling data and data of forecast results show their average residual error different from rolling modeling GM (1,1).

This discrepancy may be due to the study presents methodologies for projecting the most correctly predicts of the total coffee consumption to get the reference for Indonesia to make the action plan for the future by analyzing the precision of the Grey forecasting model.

In the end of paper, the conclusion that resulted from the analyses are presented, along with the improve the forecasting accuracy of the original Grey models, and provide a valuable reference for Indonesia coffee farmer and industries to make the action plan for the future.

2. Research Aims and Previous Studies

The fundamental purposes of the study are mention as follows:

Highlight the significance of Indonesia coffee consumption.

Arrange that a direct relationship exists between total coffee consumption and total coffee production in Indonesia.

Characterize alternative tools in Grey method to make forecasting useful for decision and policy makers need in future prediction of coffee consumption.

The proposed research is significant as not only highlights the importance of Grey forecasting method to Indonesia coffee consumption but provides strategies that can create knowledge in the total production of coffee in a more cost effective and efficient manner to the future.

Besides, there are many studies that have addressed the issue of prediction using Grey forecasting method. This table below shows several of longitudinal studies by the other researchers:

Table 1. *The most important researchers using Grey forecasting.*

Researcher	Year
Deng Julong	1982
Xianmin Wang	1999
Chin-Tsai Lin	2003
Sue J. Lin	2007
Chiun-Sin Lin	2011
Rotchana Intharathirat	2015
Liping Zhang	2017

3. Methodology

A considerable amount of literature has been published on Grey theory, developed by Deng [3] in 1982, is suitable for short-term forecasting, and does not rely on a statistical method.

Also, the Grey forecasting method has been successfully applied in many areas of research including finance, engineer, agriculture and management. Furthermore, in Grey generating system such as Grey relational analysis, Grey forecasting, Grey decision, and Grey controller are the mainly methodology of Grey system theory.

However, in this study we focus on the forecasting method is significantly by applying the transformed Grey rolling modeling mechanism. This rolling modeling mechanism provides a means to guarantee input data are always the most recent values. In another major study Zheng et al [31], this research applied the general GM (1,1).

In consequence an expression introducing the comparison of rolling modeling data and fundamental data of forecast results show as Figure 1. The average residual error different rolling modeling GM (1,1).

For instance, in Method 1: Choose first four continuous data to predict the 5th of the output value, 2nd to 5th consecutive data to predict the 6th output value and thereafter. Besides, in Method 2: forecast the 6th of the production value by adopting first five consecutive data, 2nd to 6th consecutive data to forecast the 7th output value and henceforth.

Furthermore, the study presents methodologies for projecting the most accurately predicts of the amount of coffee consumption in Indonesia by testing the precision of the Grey forecasting model.

Detailed examination by Deng [3] proposed the Grey system theory to build a Grey model for forecasting.

Accumulated Generation Operation (AGO): Accumulating obtained systematic regularity discrete the time series data.

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), ..., x^{(0)}(n)) \tag{1}$$

$x^{(1)}$ *is* $x^{(0)}$ one-order accumulated generating operation (AGO) sequence, that is,

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

Inverse-accumulated generating operation (IAGO):

$$\hat{x}^{(0)}(k) = x^{(1)}(k) - x^{(1)}(k-1)$$

Gray Derivatives.

$$z^{(1)} = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1) \tag{3}$$

Gray Difference Equation Derivatives. The first order differential equation of GM(1,1) model is $dx/dt + ax = b$, where t denotes the independent variables in the system, a represents the developed coefficient, b is the Grey controlled variable, moreover a and b denoted the parameters requiring determination in the model. When a model is constructed, the differential equation is $x^0(k) + az^{(1)}(k) = b$, including $k = 2,3,...,n$, where a, b denoted standby substantial number, this differential equation $x^{(0)}(k) + az^{(1)}(k) = b$ is called as GM (1,1) model.

$$Y_N = BA, \quad B^T Y_N = B^T BA, \quad A = (B^T B)^{-1} B^T Y_N$$

Furthermore, accumulated matrix a and b are as below expand equations:

$$a = \frac{\sum_{k=2}^{n} z^{(1)}(k) \sum_{k=2}^{n} x^{(0)}(k) - (n-1) \sum_{k=2}^{n} z^{(1)}(k) x^{(0)}(k)}{(n-1) \sum_{k=2}^{n} \left[z^{(1)}(k) \right]^2 - \left[\sum_{k=2}^{n} z^{(1)}(k) \right]^2} \tag{4}$$

$$b = \frac{\sum_{k=2}^{n} [z^{(1)}(k)]^2 \sum_{k=2}^{n} x^{(0)}(k) - \sum_{k=2}^{n} z^{(1)}(k) \sum_{k=2}^{n} z^{(1)}(k) x^{(0)}(k)}{(n-1) \sum_{k=2}^{n} [z^{(1)}(k)]^2 - [\sum_{k=2}^{n} z^{(1)}(k)]^2} \tag{5}$$

Whitening Equation:

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

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

where $x^{(1)}(1) = x^{(0)}(1)$.

Utilize Inverse-accumulated generating operation (IAGO) equation as below:

$$\hat{x}^{(0)}(k+1) = x^{(1)}(k+1) - x^{(1)}(k) = (1 - e^{a}) \left[x^{(0)}(1) - \frac{b}{a} \right] e^{-ak} \tag{6}$$

4. Data Analysis and Results

The results of this study indicate that data series from International Coffee Organization [32] used to forecast the total of coffee consumption in Indonesia.

This study produced results that corroborate the findings of several previous studies in this field.

What is noteworthy in Table 2 is that the raw data of coffee consumption in Indonesia from 1990 to the 2017 year.

Focus on 2007 to 2011 have the similar number, in this case, we need to modify a little number because the model cannot run the same number.

Table 2. *Total of domestic coffee consumption in Indonesia (thousand 60kg).*

Crop year	Real Data	Crop year	Real Data
1990/91	1,242	2004/05	2,000
1991/92	1,280	2005/06	2,500
1992/93	1,319	2006/07	2,833
1993/94	1,359	2007/08	3,333.00
1994/95	1,400	2008/09	3,333.00
1995/96	1,443	2009/10	3,333.00
1996/97	1,486	2010/11	3,333.00
1997/98	1,532	2011/12	3,667
1998/99	1,578	2012/13	3,900
1999/00	1,626	2013/14	4,167
2000/01	1,676	2014/15	4,333
2001/02	2,000	2015/16	4,500
2002/03	1,779	2016/17	4,600
2003/04	1,833	2017/18	4750*

*Forecasting 5percent residual error
Source: International Coffee Organization

In Figure 1, we can see that the different estimate between the real data and the forecast from Grey model theory. This result explained by the fact that line chart in blue color indicate the actual data and the red color indicate the forecast from Grey forecasting.

It is apparent in Figure 1 that the forecast from 5 to 11 years period remained stable stated that Grey forecasting method showed the significant correlation between the real data with the Grey forecasting method.

The present findings seem to be consistent with the results of previous research, showing that Grey forecasting method can be used to predict the future of total domestic coffee consumption in Indonesia.

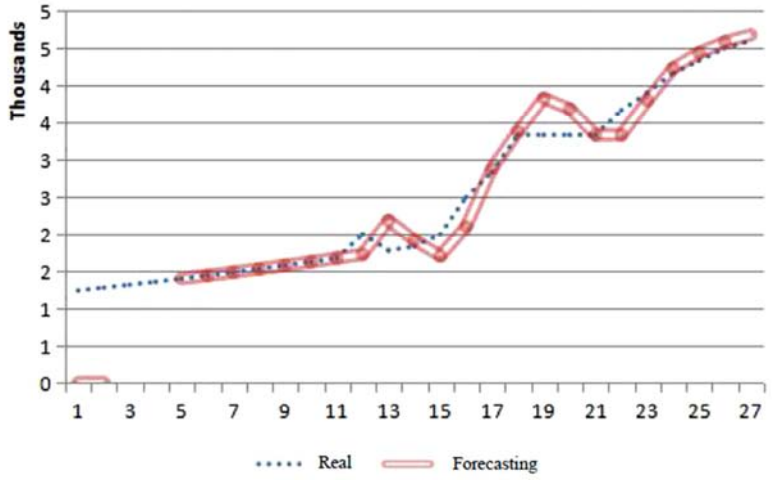

Figure 1. *Rolling model for forecasting from 1990 to 2017.*

An optimum number to forecast the total of domestic coffee consumption in Indonesia has been developed with α = 0.4 [7, 8, 16, 28, 31], data series length m = 4, and data series step Δ = 1.

Slightly worse prediction results are obtained with α = 0.4, m =4 and Δ = 12, that is with the prediction from the same month of the previous years. Such data on GM (1,1) prediction of total coffee consumption in Indonesia from Table 2 are given in Table 3. In addition, there are the results for a four years period.

However, for the purpose of analysis in Table 3 we can see that the lower error is more than 5 in 4 years and it is also the error higher around more then 8 in 12 years. According to the average residual error that indicate the data time series about total data consumption of coffee in Indonesia is suitable to use Grey forecasting method.

Table 3. *Average residual error.*

Percent	Total Error	Percent	Total Error
1-3year	-	8-year	7.52
4-year	5.2	9-year	7.59
5-year	6.25	10-year	7.59
6-year	7.08	11-year	8.37
7-year	7.48	12-year	8.43

5. Prediction Evaluation

The evaluation of GM (1,1) method in this study used to forecast the amount of domestic coffee consumption in Indonesia from 1990 to 2017.

The results presented that the average accuracy of the forecasting model exceeds 85 percent. The model thus clearly

has high prediction validity and is a viable goal for forecasting the total of domestic coffee consumption in Indonesia.

Moreover, from the forecast shows that the total of coffee consumption in Indonesia will continue to increase, and it will drive to make a new plan for road-mapping in the future, and from the forecast, the result can count the total of production coffee from Indonesia to prepare a better plan in the future.

This also agrees with our earlier observations, which demonstrated that result can explain and forecast for instance, in Method 1: choose first four continuous data to forecast the 5^{th} of output value, 2^{nd} to 5^{th} consecutive data to forecast the 6^{th} output value and thereafter, in Method 2: Predict the 6^{th} of output value by adopting first five consecutive data, 2^{nd} to 6^{th} consecutive data to forecast the 7^{th} output value and henceforth.

In consequence of result, it is can be seen from the results shows that the Grey forecasting model exhibits highest forecast accuracy and an average accurate rate at the average residual error of the Grey forecasting model is almost over 95 percent.

The above statistics confirm the efficiency of the proposed forecasting model. In such a way, the forecasting method by applying the Grey rolling model is the most accurate predictive method to the trend of the total of domestic coffee consumption in Indonesia.

6. Discussion and Future Work

Grey system modeling from GM (1,1) usually exhibits maximum accuracy for = 0.5. As can be seen in Figure 1, the result of forecasting the total of domestic coffee consumption in Indonesia depends on the original data.

We can see the data in 2007 to 2011 the data almost the same have some number, and we should change a little number to get the result because the system cannot run the same number. In GM (1,1) used for the demand of coffee consumption to forecast the number of error nevertheless, the parameter starts from 5.2 until 8.43 in Table 2.

However, in other cases, the accuracy of the forecasting depends highly on the data series used for forecasting. In short, data series should approximate with several characteristic signs such as given in Table 3.

In future investigations, it might be possible to use a different Grey forecasting model in total coffee production in Indonesia about export and import.

Hence, the Grey prediction method also will lead to another research focus on such the price of coffee in the future with the different target market.

Further study smidgen a greater focus on export is suggested because Indonesia is the one of the world's top coffee producing and exporting countries.

7. Conclusion

The key features of the Grey forecasting method are to predict data series to get future prediction number using previous data.

In this paper, the Grey system modeling based on the experimental results for forecasting the total of domestic coffee consumption in Indonesia were examined and showed the number about 5.2 percent total error to predict range one until four years.

As a result of the test that was conducted that the total of domestic coffee consumption in Indonesia increases year by year according to the real data and the Grey forecast method.

In conclusion, it can be said that Indonesia government, coffee farmer, and industries should make the action plan for the future to develop coffee sectors in all aspects because of the coffee market nowadays develops rapidly in over the world.

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