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# MODELING OF INFLUENCE FACTORS PERCENTAGE OF GOVERNMENTS' RICE RECIPIENT FAMILIES BASED ON THE BEST FOURIER SERIES ESTIMATOR

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Corona Virus Disease 2019 (COVID-19) pandemic has disrupted the targets of most countries including achieving the Sustainable Development Goals (SDGs), such as minimize poverty and hunger levels. For this reason, Indonesia's Government has implemented the rice for prosperous family program. In this study, the influence factor of the percentage of poor families receiving rice for prosperous family program is modeled based on the Fourier series estimator. The selection of the best Fourier series estimator was based on the smallest Generalized Cross Validation (GCV) value for the oscillation parameter. The results of this study are the estimation of the Fourier Cosine series with oscillation parameter equals to 4 which has a GCV value of 1.2317 x $10^{-11}$, MSE of 0.0006807645, and $R^2$ of 99.412%. These results can become recommendations for the government for food security stability and provision of equals social protection for all Indonesian to achieve the SDGs target.

***Keywords:*** COVID-19, Sustainable Development Goals (SDGs), Rice for Prosperous Family Program, Fourier series Estimator

## 1. Introduction

Indonesia is still facing challenges in realizing the Sustainable Development Goals (SDGs). One of the efforts is to alleviate poverty and hunger. Corona Virus Disease 2019 (COVID-19) which has infected people around the world has caused many problems, especially in the social field. In Indonesia itself, this pandemic has led to an increase in poverty and hunger. It is recorded that the poverty rate as of March 2020 has increased to 26.42 million people. Based on this position, the percentage of poor people as of March 2020 also reached to 9.78% (Central Bureau of Statistics, 2020). In addition, the pandemic disrupted Indonesia's target of minimizing national poverty and hunger levels.

Therefore, the Indonesian government needs a way to minimize the level of poverty and national hunger by established several assistance schemes. One of them is the rice for prosperous family program. By lowering the rice for prosperous family program to the poor, the government hopes that social assistance in the form of rice each of at least 10 kilograms per beneficiary family can reduce the burden on beneficiary family expenditures by fulfilling some special needs in the food sector within a certain period without being charged redeem (Rachman et al., 2018). However, the distribution of the rice for prosperous family program assistance tended to be uneven.

Thus, it is necessary to model the percentage of the governments' rice recipient families based on the factors that influence poverty as an alternative solution to the unequals distribution of assistance. Based on Coordinating Ministry of Human Development and Culture (2018), the distribution of the governments' rice recipient families are determined based on poor or vulnerable families. The criteria for a poor family can be determined based on the widest type of building floor made of earth, unsuitable drinking water sources, unplugged lighting sources, and improper toilet or sanitation facilities. In addition, the poverty rate can also be indicated by the unemployment rate, the human development index, and the number of beneficiary families (Central Bureau of Statistics, 2018).

The purpose of this study to model the percentage of the governments' rice recipient families based on the factors that influence poverty using nonparametric regression with the Fourier series estimator. Nonparametric regression with Fourier series estimator was chosen as the method because it has flexibility in modeling data patterns whose oscillation form is unknown (Mardianto et al., 2019). This model can be used as a recommendation and evaluation for the government to improve food security and provide equals social protection for all Indonesian to achieve the target of minimizing the national level of poverty and hunger.

The novelty that distinguishes this study from other studies is the use of the Fourier series estimator for multi predictor case in nonparametric regression to model the influence factor on the percentage of the governments' rice recipient families. Several studies using the Fourier series estimator in multi predictor nonparametric regression have been conducted by Mariati et al. (2019) regarding the Fourier series regression modeling that applied poverty data in Papua Province and Mardianto et al. (2018) related to semiparametric regression modeling with the Fourier series estimator that applied rice productivity by provinces in Indonesia.

The research on modeling the influence factor of the percentage of the governments' rice recipient families based on the best Fourier series estimator written in this article can be used as consideration in improving family welfare in Indonesia. Based on this research, it is hoped that it can provide recommendations regarding the policy of distributing prosperous rice to poor families in Indonesia.

## 2. Literature Review

### 2.1 Nonparametric Regression

To determine the pattern of the relationship between the predictor variable and the response variable whose function is unknown so that it can be linear or nonlinear, nonparametric regression methods can be used. Nonparametric regression is concerned with flexibility and only assumes a smooth functioning form (Cizek and Sadikoglu, 2019). Through the nonparametric regression approach, no assumptions must be met in modeling as in parametric regression. The nonparametric regression model can be stated as follows.

$$y_i = \eta(x_i) + \varepsilon_i; \varepsilon_i \sim N(0, \sigma^2) \tag{1}$$

with $y_i$ is the observed response variable of i-th, $\eta(x_i)$ is a function whose shape is unknown with the predictor $x_i$, and $\varepsilon_i$ is the residual of the i-th observation which is assumed to be independent, identical, and normally distributed with a mean of 0 and constant variance. There are some techniques for estimating nonparametric regression, such as the kernel estimator, the spline estimator, the wavelet estimator, the orthogonal series estimator, the histogram estimator, and the Fourier series estimator.

### 2.2 Fourier series Estimator

The Fourier series estimator is based on two parameters, namely the oscillation parameter which represents the bandwidth and the Fourier parameter. One of the advantages of the Fourier series estimator in nonparametric regression approach is that it can handle data in a periodic pattern that represented by a trigonometric function. Therefore, the Fourier series has a high degree of flexibility due to the trigonometric polynomial function that the curve shows sine or cosine functions (Mardianto et al., 2020). The complete Fourier series consists of the cosine and sine functions. Paired data is provided $(x_i, y_i)$ with $x_i$ as predictor variables and $y_i$ is the response variable in the $i^{th}$ observation, then the equation of Fourier series estimator in nonparametric regression is shown as follows.

$$y_i = \frac{\alpha_0}{2} + \omega x_i + \sum_{k=1}^{K}(\alpha_k \cos kx_i + \beta_k \sin kx_i) + \varepsilon_i; \varepsilon_i \sim N(0, \sigma^2) \tag{2}$$

with $\alpha_0$, $\alpha_k$, $\beta_k$, and $\omega$ is the regression parameter coefficient that can be determined from the optimization results of Ordinary Least Square (OLS). In this formula, $k$ is the number of oscillations or oscillation parameter in determining the approximation to the data pattern.

Paired data is provided $(x_{i1}, x_{i2}, \dots, x_{ip}, y_i)$ with $x_{ij}$ as the $j$ predictor variable in $i^{th}$ observation and $y_i$ is the response variable in the $i^{th}$ observation, then the nonparametric regression equation with the Fourier multipredictor series estimator is shown as follows.

$$y_i = \sum_{j=1}^{p} (\frac{a_{0j}}{2} + \omega_j x_{ij} + \sum_{k=1}^{K} a_{kj} \, coskx_{ij} + \beta_{kj} \sin kx_{ij}) + \varepsilon_i ; \varepsilon_i \sim N(0, \sigma^2) \quad (3)$$

The regression curve estimator in accordance with (3) is as follows:

$$\hat{y}_i = \sum_{j=1}^{p} (\frac{\hat{a}_{0j}}{2} + \widehat{\omega}_j x_{ij} + \sum_{k=1}^{K} \hat{a}_{kj} \, coskx_{ij} + \hat{\beta}_{kj} \sin kx_{ij}) \quad (4)$$

### 2.3 Measures of Goodness of the Model and Criteria for Good Predictions

The focus of this study is to acquire a nonparametric regression estimator based on the multivariable Fourier series estimator. The estimator is obtainable by completing the OLS optimization. To acquire optimal oscillation parameters, the Generalized Cross Validation (GCV) method is applied. Other methods can be compared with GCV, such as Unimplemented Risk (UBR) and Cross Validation (CV), these methods have optimal asymptotic properties (Mu et al., 2018). By looking at the minimum GCV value, it can be used to acquire optimal oscillation parameters.

In determining the measure of goodness, it can be seen with the small Mean Square Error (MSE) value on the selected oscillation parameter value. Mathematically, a small MSE value results a minimum GCV value. In addition, by looking at the coefficient of determination ($R^2$), it is used to determine the size of the goodness of the model. The ability of the dependent variable that explained by the independent variable is very limited when the value of $R^2$ is small. The value of $R^2$ describes the accuracy of the regression curve to determine the variation in response variables that can be explained by several predictor variables (Mardianto et al., 2019). A good model has a large $R^2$ value.

In addition, the measure of the accuracy of the predictive measurement results is indicated by the Mean Absolute Percentage Error (MAPE) value. MAPE is a measure of relative error, when compared with the Mean Absolute Deviation (MAD), MAPE is usually more meaningful, because MAPE states the percentage of projected error to actual observations during a certain period which will provide information that the percentage error is too high or low (de Myttenaere et al., 2016). The interpretation of MAPE results to assess the accuracy of predictions includes if the value is less than 10% it means the prediction is very accurate, and if the value is more than 50% the prediction is inaccurate (Moreno et al., 2013).

## 3. Methods

### 3.1 Data and Variables

The data used as material for this study is the percentage of the governments' rice recipient families as a response variable. The predictor variables used are related to the data on the percentage of families that have the widest building floor in the form of land, the percentage of families that have inappropriate drinking water sources, the percentage of families that have not had electricity, the percentage of families that have improper sanitation, the percentage of beneficiary families, unemployment rate, and human development index. All data used are sourced from Statistics Indonesia 2019 (Central Bureau of Statistics, 2019a), Statistics Indonesia 2020 (Central Bureau of Statistics, 2020b), District or City Poverty Data and Information for 2018 (Central Bureau of Statistics, 2018), and District or City Poverty Data and Information in 2019 (Central Bureau of Statistics, 2019b).

All the correlation coefficient ($\rho$) between response variable and each predictor variables less than 0.5 and four out of seven relationship which has p-value > 5%. This indicated that there are more predictor variables which independent of the response variable. In this study, the factors that influence the distribution of the governments' rice recipient families are modeled by dividing the data in-sample and out-sample into all provinces in Indonesia. The in-sample data was taken from the 2018 data and used for the estimation process, while the out-sample data was taken from the 2019 data and used to test the estimation results.

### 3.2 Analysis Procedure

The data analysis method used is more quantitative data analysis with the main statistical method is the Fourier series estimator in multi predictor nonparametric regression. The steps of this research data analysis are as follows:

1. Knowing the description of the literature program in Indonesia, based on the following steps:
   a. Conducting literature studies related to the description of the literature Indonesia's program based on the distribution of provinces, and their relationship with the predictor variables used.
   b. Carry out data retrieval.
   c. Determine the measure of descriptive statistics using maximum and minimum values.
2. Determining the best Fourier series estimator in nonparametric regression, by using in-sample data based on the following steps:
   a. Determine the GCV and MSE formulas depend on the estimator results of the Fourier cosine series.
   b. Creating a program for determining the optimal oscillation parameter (k) based on GCV criteria and the estimator value for nonparametric regression models using the selected Fourier cosine series approach.
   c. Calculates $R^2$ based on optimal k value.
3. Predict the distribution of the governments' rice recipient families in Indonesia and provide appropriate recommendations based on the results of data analysis.

## 4. Results and Discussion

### 4.1 Descriptive Statistics

Descriptive statistics are used to provide an overview or information related to research variable data. This study used the form of maximum and minimum values, each of which is taken by one province from each research variable as shown in Table 1 below:

Table 1: Descriptive statistics

| Variables | Maximum | | Minimum | |
|---|---|---|---|---|
| | Score | Province | Score | Province |
| Percentage of families who receive the governments' rice recipient families' assistance (Y) | 77.81% | Aceh | 0.44% | Jakarta |
| Percentage of families who have the widest building floors in the form of land ($X_1$) | 22.13% | Papua | 0.11% | Bangka Belitung |
| Percentage of families that have inappropriate drinking water sources ($X_2$) | 42.4% | Bengkulu | 0.18% | Jakarta |
| Percentage of families who not had electricity ($X_3$) | 27.63 | Papua | 0% | Jakarta |
| Percentage of families who have improper sanitation ($X_4$) | 61.73% | Papua | 5.33% | Yogyakarta |
| Percentage of Beneficiary Families ($X_5$) | 18.953% | East Java | 0.029% | Bangka Belitung |
| The highest unemployment rate ($X_6$) | 76.92% | Papua | 62.9% | South Sulawesi |
| Human development index ($X_7$) | 80.76% | Jakarta | 60.84% | Papua |

Descriptive statistics are used to provide an overview or information related to the research variable data. The measure used in this study is a maximum and minimum value, each of which is taken by one province from each research variable. Papua Province is in the highest rank of the four research variables with the percentage of families who have the widest building floors in the form of land, have not had electricity, have improper sanitation, and the highest unemployment rate in 2018 compared to other provinces in Indonesia. Meanwhile, the human development index in Papua Province is the lowest in Indonesia. This is inversely proportional to Jakarta Province which has the highest human development index in Indonesia with the percentage of families that have inappropriate drinking water sources, have not had electricity, and receive the lowest the governments' rice recipient families' assistance compared to other provinces in Indonesia. This means that the priority in the distribution of literary assistance to Papua Province will be higher than that of Jakarta.

### 4.2 Fourier series Estimator in Nonparametric Regression for Predicting the Percentage of Governments' Rice Recipient Families

An oscillation parameter (k) is used in the nonparametric regression model with the Fourier series estimator. The GCV method is used to obtain the optimum value. The optimum GCV calculation results using R software for in-sample data are presented in Table 2 below:

Table 2: Minimum GCV Score for All Fourier Series Function

| Function | k | GCV Score |
|---|---|---|
| Cos sin | 3 | $1.0176 \times 10^{-08}$ |
| **Cos** | **4** | **$1.2317 \times 10^{-11}$** |
| Sin | 4 | $2.9409 \times 10^{-10}$ |

Based on Table 2, the optimum GCV and k values can be obtained. For the best model is selected based on the smallest GCV value. In Table 2, it can be seen that the Fourier series function which gives the smallest GCV value is the Fourier series on a cosine basis. The resulting GCV value is $1.2317 \times 10^{-11}$ for k equals to 4. Table 3 presents that the GCV value for the Fourier series on a cosine basis at k equals to 4 have the smallest value compared to the surrounding k values.

Table 3: GCV Value in the Fourier Cosine Series

| **k** | **GCV Score** |
|---|---|
| 3 | 16,242.21 |
| **4** | **$1.232 \times 10^{-11}$** |
| 5 | $5.482 \times 10^{-05}$ |

Based on Table 3, the minimum GCV value in the Fourier cosine series is $1.2317 \times 10^{-11}$ where k equals to 4. Based on the optimum oscillation parameter value of 4, the Fourier series estimator in nonparametric regression is obtained as follows:

$$\hat{y}_{ij} = \frac{\hat{\alpha}_0}{2} + \hat{\omega}_1 x_{11} + \hat{\alpha}_{11} \cos x_{11} + \hat{\alpha}_{21} \cos 2x_{11} + \hat{\alpha}_{31} \cos 3x_{11} + \hat{\alpha}_{41} \cos 4x_{11} + \cdots + \hat{\omega}_7 x_{17} + \hat{\alpha}_{17} \cos x_{17} + \hat{\alpha}_{27} \cos 2x_{17} + \hat{\alpha}_{37} \cos 3x_{17} + \hat{\alpha}_{47} \cos 4x_{17} \quad (5)$$

Based on the results of calculations using R software, the parameter values in (5) can be written as follows:

$$\hat{y}_{ij} = 382.215 - 0.298x_{11} + 1.702 \cos x_{11} - 11.187 \cos 2x_{11} - 1.854 \cos 3x_{11} + 6.764 \cos 4x_{11} + \cdots - 6.000x_{17} - 18.234 \cos x_{17} + 9.232 \cos 2x_{17} - 21.206 \cos 3x_{17} + 21.595 \cos 4x_{17} \quad (6)$$

This model has a goodness criterion with an oscillation parameter value equals to 4, GCV equals to $1.2317 \times 10^{-11}$, MSE equals to 0.0006807645, and $R^2$ 99.412%. The high value of $R^2$ is caused by the high flexibility of nonparametric regression so that the curve follows the data pattern. Thus, optimal prediction caused the value of $R^2$ close to 100% but not exactly 100% (Takezawa, 2006). So, the model has met the criteria for the goodness of the model.

### 4.3 Prediction of Distribution of Literature Aid Programs and Related Recommendations

The distribution of the governments' rice recipient families' aid program in the following year is predicted to use 2019 data as out-sample data based on (6). These results are compared with data from governments' rice recipient families' aid program in 2019 as presented in Table 4 below.

Table 4: Comparison of Out-Sample Data with Prediction Results

| Prov Code | Province | Y Out Sample | Prov Code | Province | Y Prediction | Shift |
|---|---|---|---|---|---|---|
| 1 | Aceh | 67.52 | 1 | Aceh | 68.21593 | |
| 18 | West Nusa Tenggara | 65.53 | 18 | West Nusa Tenggara | 65.94477 | |
| 30 | West Sulawesi | 63.11 | 30 | West Sulawesi | 64.05242 | |
| 19 | East Nusa Tenggara | 60.9 | 19 | East Nusa Tenggara | 61.56471 | |
| 26 | Central Sulawesi | 60.55 | 26 | Central Sulawesi | 61.03821 | |
| 33 | West Papua | 57.25 | 33 | West Papua | 58.58601 | |
| 8 | Lampung | 53.94 | 8 | Lampung | 54.28389 | |
| 14 | Yogyakarta | 51.39 | 28 | South East Sulawesi | 51.93314 | ↑❷ |
| 31 | Maluku | 51.21 | 31 | Maluku | 51.90233 | |
| 28 | South East Sulawesi | 51.06 | 14 | Yogyakarta | 51.33926 | ↓❷ |
| 29 | Gorontalo | 49.53 | 29 | Gorontalo | 49.87158 | |
| 34 | Papua | 47.88 | 34 | Papua | 48.52637 | |
| 27 | South Sulawesi | 46.16 | 16 | Banten | 46.34966 | ↑❶ |
| 16 | Banten | 45.5 | 27 | South Sulawesi | 46.24658 | ↓❶ |
| 13 | Central Java | 45.19 | 13 | Central Java | 46.04264 | |
| 22 | South Kalimantan | 44.5 | 22 | South Kalimantan | 45.17688 | |
| 25 | North Sulawesi | 44.33 | 25 | North Sulawesi | 44.91636 | |
| 7 | Bengkulu | 42.96 | 7 | Bengkulu | 43.62794 | |
| 15 | East Java | 40.07 | 3 | West Sumatera | 41.02154 | ↑❶ |
| 3 | West Sumatera | 39.89 | 15 | East Java | 40.65741 | ↓❶ |
| 20 | West Kalimantan | 39.64 | 20 | West Kalimantan | 40.35781 | |
| 6 | South Sumatera | 38.75 | 2 | North Sumatera | 39.39427 | ↑❶ |
| 2 | North Sumatera | 38.2 | 12 | West Java | 38.76624 | ↑❷ |
| 5 | Jambi | 37.66 | 6 | South Sumatera | 38.49962 | ↓❷ |
| 12 | West Java | 37.48 | 5 | Jambi | 38.25247 | ↓❶ |
| 23 | East Kalimantan | 36.73 | 23 | East Kalimantan | 36.73239 | |
| 4 | Riau | 35.38 | 4 | Riau | 35.7305 | |
| 9 | Bangka Belitung | 32.62 | 9 | Bangka Belitung | 33.35006 | |
| 24 | North Kalimantan | 28.92 | 24 | North Kalimantan | 29.59141 | |
| 32 | North Maluku | 26.89 | 32 | North Maluku | 27.37324 | |
| 17 | Bali | 25.67 | 17 | Bali | 26.46942 | |
| 21 | Central Kalimantan | 15.99 | 21 | Central Kalimantan | 16.24081 | |
| 10 | Riau Island | 14.6 | 10 | Riau Island | 15.34821 | |
| 11 | Jakarta | 14.16 | 11 | Jakarta | 13.71452 | |

Based on the results of the ranking comparison in Table 4, there is no high shift in rank between the distribution of the governments' rice recipient families' aid program in 2019 and its predictions by province. A total of four provinces experienced a shift of two ranks, namely West Java, South Sumatra, Southeast Sulawesi, and Yogyakarta. Then, a total of six provinces experienced a shift of one rank, namely Jambi, North Sumatra, West Sumatra, East Java, Banten, and South Sulawesi. Meanwhile, the remaining 24 provinces, or 70.6% of provinces in Indonesia do not show a shift in rank. The results obtained have a MAPE value of 1.09%. In other words, this projection has an error rate of up to 1.09%.

This can be used as an indication that the model based on nonparametric regression with a Fourier series estimator to predict the distribution of the governments' rice recipient families' assistance programs is good. Using the results of this analysis, several recommendations were formulated regarding the distribution of the literary assistance program for the Indonesian government, namely as follows. Some provinces that are in the lowest rank need more attention in the distribution of literary assistance. Provinces that are in the top ranking need to be maintained in the stabilization of the distribution of literature. In addition, it also needs to be considered in terms of their welfare and ensure that the distribution of the governments' rice recipient families aid program must be distributed precisely because the distribution of the governments' rice recipient families aid program is determined based on poor or vulnerable people with the lowest 25% income level through meeting food needs.

To maximize the distribution of the governments' rice recipient families' aid program evenly across provinces in Indonesia as part of the National Food Security System, the government can conduct periodic evaluations to determine appropriate policies and regulations. Thus, social protection, especially in poverty and hunger, can be felt equally and support the achievement of the SDGs proclaimed by the Indonesian government.

## 5. Conclusion

Nonparametric regression based on the Fourier series estimator can be applied to estimate the influence factors percentage of governments' rice recipient. Based on the results of the analysis, it was found that the model has an oscillation parameter value equals to 4, GCV of 1.2317 x $10^{-11}$, MSE of 0.0006807645, and $R^2$of 99.412%. In addition, based on the predictive performance the model has a MAPE value of 1.09% which means it has very good predictive performance, so the Fourier series estimator can be used to determine recommendations based on the influence factor of the percentage of the governments' rice recipient families assistance. To minimize the level of poverty and the level of national hunger, various efforts can be made, including optimizing the potential for local foodstuffs and food diversification for provinces that still rely on this assistance to achieve food self-sufficiency and security. In addition, the government can strive to create a productive society, especially for food production to support the achievement of the SDGs in minimizing poverty and hunger levels in Indonesia.

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