Mixed Geographically and Temporally Weighted Regression Analysis of Percentage of Poverty in Java Island

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Abstract. Regression analysis is a method that can be used to analyze the linear relationship between explanatory variables with a response variable to analyze problems. The problem of poverty is one of the fundamental problems and is the center of government attention in every country especially developing countries like Indonesia, precisely in Java Island that have the largest number of poor people. In poverty data, there is spatial and temporal diversity. Besides, potential differences between regions in Indonesia allow for the diversity of data and can be locally and globally addressed so that the MGTWR method can be used. In this study using data on the percentage of poor people in regency/municipality in Java in 2012-2018. MGTWR modeling results show that the GDGP, literacy numbers, and EYS variables are global variables. Whereas the last variable of education was completed by elementary school, per capita expenditure, Raskin recipient households, residents of the 15-64 age group, and MYS were local variables. Based on the Bisquare kernel function, the MGTWR model is the best model to modeling the percentage of poor people in regency/municipality in Java with the smallest AIC value of 198.75 and PseudoR² the biggest is 72.92%. In MGTWR modeling, 5 regional groups are formed based on factors that influence simultaneously.

1. Introduction
Poverty is one of the fundamental problems that has become the center of attention of the government in every country, especially developing countries like Indonesia. Various policies, regulations, and development plans are designed to support poverty alleviation. As well as the National Team for the Acceleration of Poverty Reduction (TNP2K) as a special institution that was formed to handle and coordinate matters related to poverty reduction and alleviation in Indonesia.

According to [1] the number of poor people in Indonesia in March 2019 was 25.95 million people or 9.82% of the total population. This number is spread across various regions in Indonesia, with the largest percentage being in the Maluku and Papua regions. However, in terms of numbers, the largest number of poor people is still concentrated on the island of Java, amounting to 13.34 million people. It is still homework for Indonesia to fix this poverty problem.

The proportion of poor people based on regional characteristics will be influenced by the geographical location of an area. This can be due to differences in geographical location affecting the potential of an area. Therefore, it is necessary to have an analysis that takes into account geographical or regional location. One of them is to use the Geographically Weighted Regression (GWR) model. The GWR model is a development of global regression modeling by adding weights based on the distance from one observation location to another so that the interpretation for each location point will be different [2].
Research on the GWR model on the problem of poverty has been conducted by [3] to determine the characteristics of near-poor households in regency/municipality on the island of Java, it was found that the GWR gave better results than the global regression with the results of the local coefficient variation test. This results in the variable of non-migrant household heads (KRT), KRT working in the informal sector, and low-educated KRT having significant spatial heterogeneity or local character in each regency/municipality in Java Island.

Space and time are the two fundamental dimensions that exist in all human activities, social events, and environmental processes. Therefore, apart from spatial, time is also available information but cannot be handled in the GWR method [4]. However, the poverty rate in each region will change from time to time, so an analysis that takes into account the effects of time is needed. Then it was developed into Geographically and Temporally Weighted Regression (GTWR), where this method will produce a local model for each location and time so that the model becomes more representative [5].

Java Island, between regency/municipality that has great diversity. This is a consideration that there is a possibility of similarities in a regency/municipality on the island of Java. Using the GTWR model, the resulting parameters will be local for each location and time. If there are variables that are not significant on the test, it means that not all explanatory variables in the model have a spatial effect on the response or have a global effect. Therefore, the GTWR model can be developed into a Mixed Geographically and Temporally Weighted Regression (MGTWR) model.

MGTWR has greater accuracy than the MGWR and GTWR models under the conditions of stationarity and spatial-temporal non-stationarity. The surface temporal and spatial-temporal estimates of the MGTWR model are almost consistent with true values in experimental simulation data [6]. In practice, Research [7] uses the MGTWR model with the Kriging method to estimate its parameters, it is found that it is better to use it to analyze the development of Carbon Monoxide (CO) air pollution.

Based on this, this study aims to model data on the percentage of poor people in regency/municipality on Java Island in 2012-2018 who have spatial and temporal influences and have local and global influences on their regions using the Mixed Geographically and Temporally Weighted Regression model (MGTWR) and suspect the influencing factors.

2. Research Methods

2.1. Data
The data used is in the form of secondary data from the Statistics of Indonesia (BPS) from 2012 to 2018. The response variable used is the percentage of poor people in the regency/municipality on Java Island. The explanatory variables used are shown in Table 1 as follows:

| Description of variables                                         | References |
|------------------------------------------------------------------|------------|
| $X_1$ Gross Domestic Regional Product (Billion Rupiah)           | [10]       |
| $X_2$ People with the highest education graduated from elementary school (%) | [11]       |
| $X_3$ Literacy numbers (%)                                       | [12]       |
| $X_4$ Per capita expenditure for food (%)                        | [11]       |
| $X_5$ Raskin recipient households (%)                           | [12]       |
| $X_6$ Population according to age group 15-64 (%)                | [13]       |
| $X_7$ Expected years of schooling (EYS) (Year)                   | [12]       |
| $X_8$ Mean years of schooling (MYS) (Year)                       | [12]       |

2.2. Data Analysis Procedure
The steps of the analysis are as follows:

1. Exploring data on the percentage of poor people in regency/municipality in Java in 2012-2018.
2. Calculating the value of Variance Inflation Factor (VIF) to determine the multicollinearity of the explanatory variables, with criteria if VIF > 10 then multicollinearity occurs between variables.

3. Check spatial diversity annually on data using the Breusch Pagan (BP) test. This test uses the following hypothesis.
   \[ H_0: \alpha_2 = \cdots = \alpha_k = 0 \]
   \[ H_1: \text{there is at least one } \alpha_i \neq 0 \]
   The test statistic used is
   \[
   BP = \frac{1}{2} \left( \sum_{i=1}^{n} x_i f_i \right) \left( \sum_{i=1}^{n} x_i x_i^T \right)^{-1} \left( \sum_{i=1}^{n} x_i f_i \right) \chi^2_{(k-1)}
   \]
   with \( f_i = \left( \frac{\hat{z}_i}{\hat{\sigma}} - 1 \right) \), \( \hat{z}_i = (y_i - \hat{\beta} x_i) \), \( \hat{\sigma}^2 = \sum_{i=1}^{n} \hat{z}_i^2 \)
   Test criteria used are rejected \( H_0 \) if the test statistic value \( BP > \chi^2_{(k-1)} \) or if the p-value < \( \alpha \) with \( k \) is the number of parameters [8].

4. Analysis of the GTWR to get the coefficients to use weighted least squares.

5. Determine global variables and local variables using the confidence interval of the global regression model. Criteria for selection as a global variable if at least 70% of the GTWR coefficients are within the confidence interval [9].

6. Analysis of the MGTWR model using the two-stage least squares.
   a. Step one: calculates the global parameter estimator from \( \hat{y} \) [6].
      i. Calculates temporal-spatial ratio parameters (\( \tau \)) and temporal-spatial distance (\( d_{ij}^{ST} \)) and the width of the temporal-spatial window (\( h_{ST}^2 \)) using the Cross-Validation (CV) approach.
         \[
         CV = \sum_{i=1}^{n} (y_i - \hat{\gamma}_{i\alpha}(\tau))^2
         \]
         \[
         (d_{ij}^{ST})^2 = 2 \left[ (u_i + u_j)^2 + (v_i + v_j)^2 \right] + \mu(t_i - t_j)^2
         \]
      ii. Determine the function of the temporal-spatial weighting by using the Bisquare weighting with \( ij = 1, 2, ..., n \).
         \[
         w_{ij} = \left( 1 - \frac{(d_{ij}^{ST})^2}{h_{ST}^2} \right)^2
         \]
      iii. Calculate the weighting
         \[
         W(u_i, v_i, t_i) = \text{diag}(w_{i1}, w_{i2}, ..., w_{in})
         \]
   iv. Calculating the estimator of local variables containing global variables.
       \[
       \hat{\beta}_i(u_i, v_i, t_i) = \left[ X_i^TW(u_i, v_i, t_i)X_i \right]^{-1} X_i^TW(u_i, v_i, t_i)\hat{y}
       \]
   v. Calculating the global variable estimator.
       \[
       \hat{\beta}_g = \left[ X_g^T(I - S_i)X_g \right]^{-1} X_g^TW(I - S_i)(I - S_i)\hat{y}
       \]
       \[
       S_i = \begin{bmatrix}
       x_{1i}^T X_{1i} W(u_i, v_i, t_i) X_{1i} & x_{1i}^T X_{1i} W(u_i, v_i, t_i) \\
       x_{2i}^T X_{2i} W(u_i, v_i, t_i) X_{2i} & x_{2i}^T X_{2i} W(u_i, v_i, t_i) \\
       \vdots & \vdots \\
       x_{ni}^T X_{ni} W(u_i, v_i, t_i) X_{ni} & x_{ni}^T X_{ni} W(u_i, v_i, t_i)
       \end{bmatrix}
       \]
   b. Step two: update the local variable estimator.
\[ \hat{\beta}_l(u, v, t) = [X_l^T W(u, v, t) X_l]^{-1} X_l^T W(u, v, t) (y - X_l \hat{\beta}_g) \]

c. Determine the MGTWR model response estimator [10].

\[ \hat{y} = S y \]

\[ S = S_l + (I - S_l) X_g [X_g^T (I - S_l)^T (I - S_l) X_g]^{-1} X_g^T (I - S_l)^T (I - S_l) \]

7. Partial testing of each MGTWR parameter on global and local variables [10]

a. Test the significance of global variables with hypotheses

\[ H_0: \beta_g = 0 \] (the global variable \( x_k \) is not significant)

\[ H_1: \beta_g \neq 0 \] (the global variable \( x_k \) is significant)

Using \( X, Y \), weighter’s \( W(u, v, t) \), \( S_l \), and \( \hat{\beta}_g \) to calculate \( t_g \) calculated for each observation with the formula:

\[ t_g = \frac{\hat{\beta}_g}{\hat{\sigma}} g_{kk} \]

with \( g_{kk} \) is the k-th diagonal element of the \( GG^T \) matrix,

\[ G = [X_g^T (I - S_l)^T (I - S_l) X_g]^{-1} X_g^T (I - S_l)^T (I - S_l) \]

and

\[ \hat{\sigma}^2 = \frac{1}{n} \sum (I - S_l)^T (I - S_l) y \]. Reject \( H_0 \) if

\[ |T_{g, hit}| > t_{a/2, df} \]

with \( df = \left[ \frac{n^2}{u_2} \right] \), and

\[ u_i = tr\left( \left[ (I - S_l)^T (I - S_l) \right] \right), i = 1, 2 \]

b. Test the significance of local variables with hypotheses

\[ H_0: \beta_l(u, v, t) = 0 \] (local variable \( x_i \) at location-i is not significant)

\[ H_1: \beta_l(u, v, t) \neq 0 \] (local variable \( x_i \) at location-i is significant)

Using \( X, Y \), weighter’s \( W(u, v, t) \), \( S_l \), and \( \hat{\beta}_l(u, v, t) \) to calculate \( t_l \) calculated for each observation with the formula:

\[ t_l = \frac{\hat{\beta}_l(u, v, t)}{\hat{\sigma}} m_{kk} \]

with \( m_{kk} \) is the k-th diagonal element of the \( MM^T \) and

\[ M = [X_l^T W(u, v, t) X_l]^{-1} X_l^T W(u, v, t) (I - X_g G) \]. Reject \( H_0 \) if

\[ |T_{l, hit}| > t_{a/2, df} \]

with

\[ df = \left[ \frac{n^2}{u_2} \right] \) and

\[ u_i = tr\left( \left[ (I - S_l)^T (I - S_l) \right] \right), i = 1, 2 \]

8. Testing the goodness of the GTWR and MGTWR models based on the AIC and Pseudo R².

\[ AIC = 2n \ln(\hat{\sigma}) + 2n \ln(\mu) + \frac{n + tr(S_l)}{n - 2 - tr(S_l)} \]

\[ Pseudo R^2 = 1 - \frac{y^T (I - S_l)^T (I - S_l)y}{y^T y - \frac{1}{n} (y^T J y)} \]

where \( J \) is an n-symmetric matrix with elements of 1.

3. Results And Discussion

3.1. Data Exploration

In measuring poverty, BPS uses the concept of the ability to meet basic needs approach, namely the inability from an economic perspective to meet basic food and non-food needs as measured by
expenditure. People are said to be poor if they have an average per capita expenditure per month below the poverty line. The poverty line is the minimum amount of money needed to meet the minimum basic needs of food and non-food per person for one month. Map of the percentage distribution of poor people in the regency/municipality of Java Island for the period 2012-2018 can be seen in Figure 1.

![Map of the percentage distribution of poor people in Java](image)

**Figure 1.** Map of the percentage distribution of poor people in Java

The distribution of the percentage of poor people on the island of Java is explained in Figure 1 shows that the percentage of poor people between regency/municipality varies each year and when compared to the percentage of poor people in Indonesia, according to [1] the number of poor people in Indonesia in 2019 is 25.14 million people or 9.41 percent, the provinces of DKI Jakarta and West Java have an average percentage value below the percentage of Indonesia, while the provinces of Central Java, East Java, and DI Yogyakarta have several regencies/municipalities with a percentage of poor people above 15%. Besides, in general from 2012 to 2018, the percentage of poor people has decreased. When viewed during the 2012-2018 period, there was a decrease as seen from the reduction in the percentage of poor people above 25% which is shown on the map in red.

The linear relationship between each explanatory variable and the response variable can be seen using the Pearson correlation value in Figure 2. The positive correlation value, this means that any increase in the explanatory variable will have an impact on increasing the response variable or unidirectional relationship. Meanwhile, a negative correlation value means that any increase in the explanatory variable will have an impact on decreasing the response variable or the relationship is reversed.

![Correlation values between explanatory and response variables](image)

**Figure 2.** Correlation values between explanatory and response variables in 2012-2018
The Pearson correlation value in Figure 2 shows that most of the explanatory variables for the percentage of poor people have a strong correlation value that is close to 1 and -1. Also, broadly the variables of gross domestic regional product ($X_1$), literacy rate ($X_3$), percentage of the population according to age group 15-64 ($X_6$), expected length of schooling ($X_7$), and mean length of schooling ($X_8$) has a negative correlation value, this means that an increase or increase in these variables will be followed by a decrease in the percentage of poor people in regency/municipality on the island of Java. Whereas each increase in the percentage value of the population with education completed SD ($X_2$), the percentage of expenditure per capita on food ($X_4$), and Raskin recipient households ($X_5$) is positive, it will also be followed by an increase in the percentage value of poor people in the regency/municipality on the island of Java.

| Table 2. VIF value for each explanatory variable |
|-------|-------|-------|-------|-------|-------|-------|-------|
| $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
| 2.348 | 2.975 | 1.962 | 3.748 | 1.894 | 2.108 | 2.008 | 8.563 |

Multicollinearity examination is checked from the VIF value. Multicollinearity occurs if the VIF value is greater than ten (VIF > 10). In Table 2, it is found that all explanatory variables have a VIF value of less than ten. Therefore, it can be concluded that there is no multicollinearity between variables.

3.2. Spatial Diversity

Testing to determine heterogeneity in data due to spatial influence is done through a variety of homogeneity tests with the Breusch Pagan test for each year from 2012 to 2018 and simultaneously on 118 regency/municipality is presented in Table 3.

| Table 3. Test statistics of the Breusch Pagan |
|-------|-------|
| Years | P-value |
| 2012  | 4.60×10^{-5}a |
| 2013  | 6.44×10^{-2}b |
| 2014  | 1.28×10^{-2}a |
| 2015  | 4.68×10^{-2}a |
| 2016  | 8.53×10^{-2}b |
| 2017  | 3.26×10^{-1} |
| 2018  | 3.31×10^{-1} |
| 2012-2018 | 2.86×10^{-9}a |

a significant at $\alpha = 5$

b significant at $\alpha = 10$

The Breusch Pagan test in Table 3 shows that in the years that show diversity, namely 2012-2016 and simultaneously, the p-value is less than the real level. These results can be concluded that there are spatial and temporal variations in the data on the percentage of poor people in each district/city on the island of Java. Years that do not show spatial diversity in the data on the percentage of poor people in regency/municipality on the island of Java are only 2017 and 2018. The existence of spatial diversity at these times can be handled by the application of spatial regression with a temporal effect, namely geographically and temporally weighted regression.

3.3. Mixed Geographically and Temporally Weighted Regression

The GTWR model produces different parameter values at each location and time of observation. If there are global parameters, then the Mixed GTWR model is used. Global and local determinations are carried out based on the percentage of the GTWR model parameter estimators that fall into the parameter confidence interval of the global linear regression model. A summary of the GTWR model parameter estimators is presented in Figure 3.
In the MGTWR model, the value of each parameter estimator will be measured to determine global and local variables. If the percentage of estimator parameters for the GTWR model in a variable is more than 70% which is included in the global regression confidence interval, then the variable is grouped into global variables. Meanwhile, if it is less than 70%, it is grouped into local variables. The results of the division of global and local variables are presented in Table 4.

### Table 4. Interval confidence parameters of global regression

| Variable | Interval confidence | Parameter Estimator (%) | Information |
|----------|---------------------|-------------------------|-------------|
| X1       | -0.32 < β₁ < 0.02  | 96.85                   | Global      |
| X2       | -0.09 < β₂ < -0.02 | 32.93                   | Local       |
| X3       | -1.35 < β₃ < -0.03 | 77.36                   | Global      |
| X4       | -0.44 < β₄ < 0.39  | 62.11                   | Local       |
| X5       | 2.72×10⁻³ < β₅ < 4.92×10⁻³ | 59.08 | Local |
| X6       | -0.99 < β₆ < 0.29  | 49.15                   | Local       |
| X7       | 3.07 < β₇ < 5.37   | 80.75                   | Global      |
| X8       | -0.28 < β₈ < -0.20 | 48.91                   | Local       |

Based on Table 4, shows that the variables X₁, X₃, and X₇ are global variables. While the variables X₂, X₄, X₅, X₆, and X₈ are local variables. The presence of global and local variables is handled using the MGTWR model. MGTWR modeling is done using the Bisquare kernel function selected based on the smallest cross-validation (CV) value. Based on the kernel function, the temporal-spatial ratio (r) value is 0.019, the spatial distance parameter (λ) is 0.993, the temporal distance parameter (μ) is 0.019, and the temporal-spatial window width value (hST) is 4,625.

### 3.4. MGTWR Model Parameter Estimator

MGTWR model has global and local models, for global one variable has the same parameter estimator for each location and time. Meanwhile, local variables have different parameter estimators for each location and every time. The estimator of global parameters from the MGTWR model, namely the...
parameter $\hat{\beta}_1$ or gross domestic regional product of -0.13 and $\hat{\beta}_3$ or the literacy number of -0.77 is a parameter estimator that is negative, meaning that every one-unit increase in the value of the variable when the other variables are fixed, the percentage The poor population on the island of Java for the years 2012-2018 will decline. Whereas $\hat{\beta}_2$ or the expected number of years of schooling of 0.97 has a positive meaning that every one-unit increase in the value of this variable while the other variables are constant, the percentage of poor people in Java for the years 2012-2018 will increase. Parameter $\hat{\beta}_4$ or percentage of poor people with education completed SD, $\hat{\beta}_5$ or percentage of expenditure per capita on food, $\hat{\beta}_6$ or Raskin recipient households, $\hat{\beta}_8$ or percentage of population by 15-64 age group, and $\hat{\beta}_9$ or average length of time school is a local variable, so $\hat{\beta}_2, \hat{\beta}_4, \hat{\beta}_5, \hat{\beta}_6,$ and $\hat{\beta}_8$ have a different effect on the percentage of poor people in each regency/municipality on the island of Java in 2012-2018 which summaries are presented in the form of a box line diagram in Figure 4.

![Box diagram for estimating parameters for the GTWR and MGTWR](image)

Information: a = GTWR model; b = MGTWR model

**Figure 4.** Box diagram for estimating parameters for the GTWR and MGTWR

In Figure 4, in the MGTWR model the parameter $\hat{\beta}_2$ or the percentage of education that has completed primary school education is below, $\hat{\beta}_4$ or the percentage of per capita expenditure and $\hat{\beta}_6$ or the percentage of the population according to the 15-64 age group consisting of positive and negative values. The parameter $\hat{\beta}_4$ or Raskin recipient households has a positive value. Conversely, $\hat{\beta}_6$ or the mean length of schooling has a negative predictive value. When a summary comparison of the local parameter estimators of the GTWR model and the MGTWR model is compared, it is found that the average value does not change too much. However, it can be seen that MGTWR models have different data widths. This also applies to the global parameters $\hat{\beta}_1$ and $\hat{\beta}_3$, which have an estimated beta value of the MGTWR model which is close to the average value of the beta estimator of the GTWR model.

The partial test of variables is done by using the t test, for global and local parameters. Based on the results of the partial test of global variables, it is found that with a significance level ($\alpha$) of 5%, it can be concluded that the global explanatory variable $X_1$ or gross domestic regional product with a value of t-count -1.61 and $X_7$ or the expected number of school years with a t-count of 1.64 has no significant
effect on The percentage of poor people on the island of Java, while $X_3$ or the literacy rate per capita with a $t$-count of -2.46 has a significant effect on the percentage of poor people in Java.

Local explanatory variables in the MGTWR model have different effects at each location and time so that each regency/municipality has a different effect. The partial test results for local variables are presented in the form of a distribution map in Figure 5.

![Figure 5](image_url)

**Figure 5.** Map of the distribution of significant local parameters of the MGTWR model test

Based on the results of the partial test, 5 groups of locations were formed. This group of locations is formed based on the same influencing factors. In Figure 5, the years 2012 and 2013, as well as from 2014 to 2017, areas in Java Island have the same influencing factors. This means that between years there are not many changes in the factors that affect the percentage of poor people in Java. This is thought to be influenced by the existence of spatial diversity between years in table 2 that there are years that do not have spatial diversity. Changes in influencing factors occurred in 2013 to 2014 and 2017 to 2018. From 2013 to 2014 there was a reduction in the percentage of expenditure per capita, namely in Bangkalan, East Java, and in 2017 to 2018 there was a change in Malang, East Java, namely the addition percentage factor of the population by 15-64 age group.

3.5. **Comparison of Model Goodness**

Comparison of the goodness of the global regression, GTWR, and MGTWR models was carried out to see which model is better to apply to the data on the percentage of poor people in Java from 2012-2018.
The criteria used is to compare the \( Pseudo \ R^2 \) and AIC values as in Table 5. The best model is the model with the highest \( Pseudo \ R^2 \) and the smallest AIC value.

**Table 5. Comparison of model goodness**

|                  | \( Pseudo \ R^2 \) | AIC        |
|------------------|---------------------|------------|
| Global Regression| 0.6461              | 389.2372   |
| GTWR             | 0.6921              | 252.9846   |
| MGTWR            | 0.7292              | 198.7532   |

Based on the summary results of the goodness of the models in Table 5, it is found that the MGTWR model has the largest \( Pseudo \ R^2 \) value and the smallest AIC value compared to the global and GTWR regression models. This means that the MGTWR model is better used for modeling the percentage of poor people in Java in 2012-2018.

4. Conclusion

Based on the MGTWR model using the Bisquare kernel weighting, the factors that influence the percentage of poor people in regency/municipality on the island of Java in 2012-2018 are locally formed 5 location groups. Meanwhile, globally, the literacy rate factor has a significant influence on the percentage of poor people in regency/municipality on the island of Java. The MGTWR model has the largest \( Pseudo \ R^2 \) value and the smallest AIC value compared to the global regression model and the GTWR model.

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