

Modeling PLN Inc. Customer Receivables Based on Geographically Weighted Regression Approach

Shalwa Oktavriliana Kusuma¹, Marshanda Aprilia², Toha Saifudin^{3✉},
Sa'idah Zahrotul Jannah⁴

^{1, 2, 3, 4} Statistics, Faculty of Science and Technology, Airlangga University, Indonesia

Article Information

Article History

Received : May 31, 2024

Revised : June 12, 2024

Accepted : June 14, 2024

Keywords:

*Customer Receivables;
Geographically Weighted
Regression; Government Debt;
PLN Inc.; sustainable
economic growth*

Kata Kunci:

*Geographically Weighted
Regression; Piutang
Pelanggan; PT PLN
(Persero); SDGs; Utang
Negara*

ABSTRACT

PLN Inc. implements a postpaid service that has resulted in many customer receivables issues. Customer receivables disrupt PLN Inc.'s cash flow, requiring the government to inject funds from the state budget. If the state budget experiences a deficit, it can increase the national debt. National debt impacts the achievement of SDG goals, namely sustainable economic growth (SDG 8), reducing inequalities (SDG 10), and financing infrastructure that supports development (SDG 9). The largest receivables occur on the island of Java, where many companies have high electricity consumption, while outside Java, electricity consumption is lower due to the scarcity of companies. This indicates a spatial influence on the size of PLN Inc.'s customer receivables, so this research was conducted using the Geographically Weighted Regression (GWR) method. The study found that the best weighting was fixed Gaussian with an R^2 value of 96.94%, which is better than the global regression value of 44.34%.

ABSTRAK

PT PLN (Persero) menerapkan layanan pasca bayar yang menimbulkan banyak masalah piutang pelanggan. Piutang pelanggan menyebabkan perputaran dana PT PLN (Persero) terganggu, sehingga pemerintah harus menyuntikkan dana yang berasal dari alokasi APBN. Apabila APBN mengalami defisit, dapat menyebabkan utang negara bertambah. Utang negara memiliki dampak pada pencapaian tujuan SDGs, yaitu pertumbuhan ekonomi yang berkelanjutan (SDGs ke-8), pengurangan kesenjangan (SDGs ke-10), dan pembiayaan infrastruktur yang mendukung perkembangan (SDGs ke-9). Piutang terbesar terjadi di pulau Jawa karena banyak perusahaan dan perkantoran yang konsumsi listriknya besar sedangkan diluar pulau Jawa memiliki konsumsi listrik yang rendah karena jarang terdapat perusahaan. Hal ini menunjukkan adanya pengaruh spasial dalam besarnya piutang pelanggan PT PLN (Persero), sehingga penelitian ini dilakukan dengan metode Geographically Weighted Regression (GWR). Berdasarkan penelitian didapatkan pembobot terbaik yaitu fixed gaussian dengan nilai R^2 sebesar 96,94% yang lebih baik dari regresi global yaitu sebesar 44,34% menunjukkan bahwa metode GWR merupakan metode terbaik.

Corresponding Author :

Toha Saifudin

Statistics, Faculty of Science and Technology, Airlangga University, Indonesia

Jl. Dr. Ir. H. Soekarno, Mulyorejo, Kec. Mulyorejo, Surabaya, Jawa Timur 60115

E-mail: toha_saifudin@unair.ac.id

INTRODUCTION

PLN Inc. is a state-owned enterprise providing electricity in Indonesia (Sya'diyah, 2021). It is also a monopolist in Indonesia's electricity sector. Energy is one of the basic and main needs that are needed at this time (Tahir & Irsan, 2024). Since electricity is one of the basic needs, It provides the service to all layers of society from various backgrounds, including households, industries, businesses, and public and social sectors (Wattimena et al., 2012). PLN Inc. implements post-paid services for its customers, allowing them to use electricity beforehand for a generally one-month period. It generates post-paid meter records, then calculates and issues the bills to be paid by customers for each month. Additionally, billing is pursued for customers who are late or fail to pay on time. The electricity will be disconnected if customers persistently delay or fail to settle their bills after a specific deadline (Talakua et al., 2018). This post-paid service can be an issue if customers fail to pay their electricity bills promptly.

PLN Inc. Statistical Publication in 2022 showed that customer receivables in 2022 are IDR 25,395,928.06. The customer receivables fluctuate from 2018 to 2022, experiencing a decrease from 2018 to 2020 and then increasing from 2021 to 2022. The increase is caused by some factors, including a lack of human resources to disconnect electricity as a sanction for late-paying customers. PLN's officers are not firm to them. Therefore, they do not take it as a consequence for not paying the bills. High customer receivables can affect sovereign debt because the government pays electricity tariff compensation to PLN Inc. to cover the cost of electricity supply, which is higher than the electricity sales tariff for non-subsidized groups. In 2021, the government paid compensation costs of IDR 24.59 trillion using the state budget allocation (APBN). The increase in APBN funds will increase government debt, which will hinder the implementation of sustainable development programs in Indonesia. The welfare of society is the primary goal of every country. Welfare is considered as an indicator of national development (Matdoan et al., 2016). Sovereign debt management can be linked to several SDG targets, particularly in the context of sustainable economic growth (SDG-8), reducing inequality (SDG-10), and financing infrastructure that supports development (SDG-9). Therefore, although sovereign debt is not specifically mentioned in the SDGs, it can significantly impact the goals.

The most considerable customer receivables of PLN Inc. occur in densely populated areas such as on the Java Island. Some provinces outside Java, do not get the electricity service evenly. In 2021, Java consumed up to 73.5% of electricity, probably due to the large number of companies and offices and factories that consume much electricity, while Sulawesi, Bali-Nusa Tenggara, and Papua-Maluku have lower electricity consumption, which is 2.6%, 0.8%, and 0.2% respectively. This shows that there is a spatial (geographical) influence on the amount of PLN Inc. customer receivables. Since this study aims to analyse the factors influencing customer receivables, the appropriate method is Geographically Weighted Regression (GWR).

GWR is a localized form of regression (Fadli et al., 2018). GWR allows researchers to assess the spatial (geographic) variation that may exist in the relationship between dependent and independent variables across observation areas (Clement et al., 2009). In that kind of variable relationship, GWR is more appropriate to describe the data than OLS because GWR results in a higher Adjusted R^2 value and a smaller AIC value than the OLS model. Based on the problem of PLN Inc.'s customer receivables, this study aims to provide an overview of the factors that may influence it. The factors are the average speed of collection (in days), the number of employees, employee productivity, and the percentage of customer revenue. The result of this study can be used as evaluation material to solve customer receivable problems in the future.

RESEARCH METHODS

Data Sources

This study used data from the official website of PLN Inc. The data taken is the statistical publication data of PLN inc in 2022.

Research Variables

The variables used in this study consist of variables that can affect the amount of PLN Inc. customers receivables in Indonesia. The research variables used in this study are as follows :

Table 1. Research Variables

Variables	Description	Scale	Unit
Y	Customer Receivables	Ratio	Million
X_1	Average Billing Speed	Ratio	Day
X_2	Number of Employees	Ratio	People
X_3	Employee Productivity	Ratio	-
X_4	Revenue from Customers	Ratio	Percent (%)

Steps in Data Analysis

The following are the steps in analyzing data using the Geographically Weighted Regression (GWR) method.

1. Modeling PLN Inc. customer receivables by province in Indonesia using a linear regression approach.
2. Testing assumptions on spatial analysis.
3. After testing the spatial assumptions are met, the next step is to model PLN Inc. customer receivables by province in Indonesia using the GWR approach.
4. Visualize the distribution map of the estimated results of PLN Inc. customer receivables in Indonesia along with factors that have a significant influence on PLN Inc. customer receivables in each province in Indonesia.

RESULTS AND DISCUSSION

Descriptive Analysis of Research Variables

Descriptive analysis aims to represent an overview of the research variables. The description of the characteristics of the research variable PLN Inc. Customer Receivables (Y) and the variables that may affect it is shown in Table 2.

Table 2. Description of the Research Variables

Variables	Minimum	Average	Maximum
Y	45	1,104	5,194
X_1	11.36	27.50	36.84
X_2	355	1,058	2,224
X_3	695	3,005	7,734
X_4	0.47	4.35	20.20

Table 2 shows the mean or average, maximum, and minimum values of each research variable. In accordance with Table 1, it is known that the average customer receivables of PLN Inc. in Indonesia in 2022 is IDR 1,104,000,000,000 with a minimum PLN Inc. customer receivables value of IDR 45,000,000,000 in NTT Province and a maximum of IDR 5,194,000,000,000 in West Java Province.

Multiple Linear Regression Modeling

Multiple linear regression modeling on PLN Inc. Customer Receivables data against factors that may affect it is carried out using the OLS method. This modeling begins with multicollinearity detection in the data, followed by parameter estimation, parameter significance test, and residual normality assumption test.

a. Multicollinearity Test

To test for correlation between independent variables in the regression model using multicollinearity test. The existence of a perfect linear relationship between variables that explain the regression model is the definition of multicollinearity (Ajija et al., 2011). This test aims to analyze whether there is a correlation between independent variables in a regression model

(Ghozali, 2016). A multicollinearity test is conducted to detect a strong relationship between predictor variables, which is based on the VIF value. Table 3 shows the multicollinearity results.

Table 3. Multicollinearity Test Results

Predictor Variables	Description	VIF
X_1	Average Billing Speed	1.13
X_2	Number of Employees	3.67
X_3	Employee Productivity	3.57
X_4	Revenue from Customers	7.12

Based on **Table 3**, all predictor variables have VIF values smaller than 10, so it is concluded that there is no indication of multicollinearity between the predictor variables. Thus, the analysis can be continued to model PLN Inc. Customer Receivables against all predictor variables using multiple linear regression methods.

b. Parameter Estimation of Linear Regression Model

The technique of estimating the parameter of independent variables in regression analysis is called Ordinary Least Square (OLS). OLS has several statistical properties, making it one of the most potent and popular regression analysis methods (Gujarati, 2003). Parameter estimation of the linear regression model aims to determine the relationship between predictor variables and PLN Inc. Customer Receivables globally using the OLS method. The estimation results are summarized in **Table 4**.

Table 4. Parameter Estimation of Linear Regression Model Results

Parameters	Estimations
$\hat{\beta}_1$	157.6002
$\hat{\beta}_2$	13.8118
$\hat{\beta}_3$	-0.7379
$\hat{\beta}_4$	0.0060
$\hat{\beta}_1$	305.7316

The equation form of the estimation results can be written in Equation (1) below.

$$Y = 157.6002 + 13.8118X_1 - 0.7379X_2 + 0.0060X_3 + 305.7316X_4 \quad (1)$$

Based on Equation (1), it can be seen that when the number of employees (X_2) increases by one person, the customer receivables of PLN Inc. will decrease by 0.7379 with other predictor variables considered constant. Conversely, if the average billing speed (X_1) increases by one unit, the customer receivables of PLN Inc. will increase by 13.8118 with other predictor variables held constant. All predictor variables in the model with positive coefficients have the same interpretation.

c. Significance Testing of Linear Regression Model Parameters

In identifying the parameters that affect customer receivables, partial testing is carried out on each parameter through the formulation of the following hypothesis.

$$H_0: \beta_k = 0 \quad (\text{There is no effect of predictor variables } x_k)$$

$$H_1: \beta_k \neq 0; k = 1, 2, \dots, 4 \quad (\text{There is an effect of predictor variables } x_k)$$

The test statistic used is the T test with $\alpha = 10\%$, then decision making is done by rejecting H_0 if the test statistic value $|T_k| > t_{(0.05;5)} = 2.57$ or $p\text{-value} \leq \alpha$ (0.1). The results of partial parameter significance testing are summarized in **Table 5**.

Table 5. Significance Testing of Linear Regression Model Parameters Results

Parameters	T-Value	P-Value	Conclusions
$\hat{\beta}_1$	1.22	0.238	Accept H_0
$\hat{\beta}_2$	-2.99	0.008	Accept H_0
$\hat{\beta}_3$	0.09	0.928	Accept H_0
$\hat{\beta}_4$	9.25	0.000	Reject H_0

Based on **Table 5**, with $\alpha = 10\%$ it is known that partially only the predictor variable of the percentage of poor people (X_4) significantly affects the customer receivables of PLN Inc.

d. Residual Normality Testing

Data from a normally distributed population or in a normal distribution is known from the normality test procedure. The normality test aims to determine that sample data is logical and

comes from a specific population with a normal distribution (Budiwanto, 2017). The residual is examined using the Kolmogorov-Smirnov test to check the residual normality assumption with the following hypothesis.

H_0 : Residual data is normally distributed

H_1 : Residual data is not normally distributed

With a significant level $\alpha = 10\%$, H_0 is rejected if the value of $D > D_{0.1} = 0.209$ or $p\text{-value} \leq \alpha = 10\%$. The plot of the residual normality test results is shown in Figure 1.

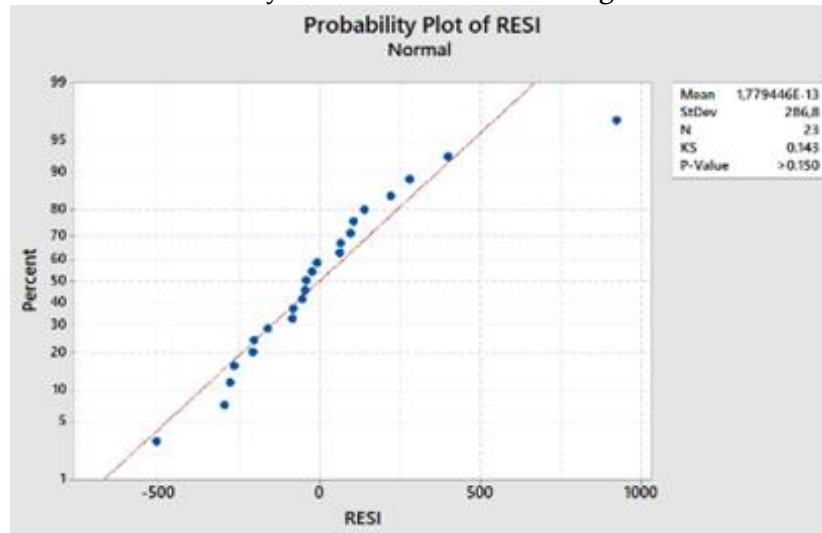


Figure 1. Plot of Residual Normality Test of Linear Regression Model

Based on **Figure 1**, the $p\text{-value} > 0.150$ and the value of $D (0,143) \leq 0.209$, with the $\alpha = 10\%$ it can be decided to fail to reject H_0 . Thus, it can be said that the residuals of the regression model fulfill the assumption of normality.

e. Coefficient of Determination

The coefficient of determination (R^2) is used to determine how much influence the predictor variables have on the amount of variation in the response variable. The model is said to be good if the coefficient of determination is large. Based on the analysis with multiple linear regression, the coefficient of determination or R^2 is 44.34%. This value shows that the variables X_1 , X_2 , X_3 , and X_4 can explain 44.34% of the variation that occurs in the variable y and the rest is explained by other variables not included in the model. Because the coefficient of determination is not too large, PLN Inc. customer receivables with a combination of predictor variables X_1 , X_2 , X_3 , and X_4 are not well modeled with multiple linear regression.

Spatial Assumption Test

Testing spatial assumptions on data needs to be done as an initial stage before modeling with spatial regression. This test aims to determine whether there are differences in characteristics and relationships between regions with one another. Spatial assumption tests include spatial dependency and heterogeneity tests.

a. Spatial Dependency Test

Testing the effects of spatial dependence must be addressed because it can lead to inefficient estimates and incorrect or inappropriate conclusions (Usali et al., 2021). This assumption test aims to detect the relationship between the residuals of the response variable in a region and the surrounding areas. The test is conducted with Moran's I test through the following hypothesis formulation.

$H_0 : I = 0$ (There is no spatial dependency in the data)

$H_1 : I \neq 0$ (There is spatial dependency in the data)

with $\alpha = 10\%$ then H_0 rejected if the $p\text{-value} \leq \alpha$. The results of testing the assumption of spatial dependence are summarized in **Table 6**.

Table 6. Spatial Assumption Test Results

<i>Observed</i>	0.1913505
<i>Expected</i>	-0.04545455
<i>SD</i>	0.04522446
<i>P-Value</i>	0.0000001639014

Based on **Table 6**, the *p-value* ($0.0000001639014 \leq \alpha = 10\%$) is obtained. Therefore, it can be concluded that the PLN Inc. customer receivables data between provinces in Indonesia is indicated by spatial dependency so that the spatial assumption is fulfilled.

b. Spatial Heterogeneity Test

Spatial heterogeneity is when the same independent variable responds differently in different locations within a study area (Desriwendi et al., 2015). This test aims to identify the variation of the response variable residuals in each location. Testing is done with the Breusch Pagan test through the following hypothesis.

$$H_0 : \sigma_1^2 = \sigma_2^2 = \dots = \sigma_n^2 = \sigma^2 \quad (\text{homoscedasticity})$$

$$H_1 : \text{at least } \sigma_1^2 \neq \sigma^2 \quad (\text{heteroscedasticity})$$

with $\alpha = 10\%$ then H_0 is rejected if the value of $BP > X_{0.1,4}^2 = 7.779$ or *p-value* $\leq \alpha$. The results of testing the assumption of spatial heterogeneity are summarized in **Table 7**.

Table 7. Spatial Heterogeneity Test Results

<i>Breusch Pagan Test</i>	8.0726
<i>df</i>	4
<i>P-Value</i>	0.08895

Based on **Table 7**, this test produces a BP test statistic value of 8.0726 so that it can be decided to reject H_0 because the value of $BP(8.0726) > 7.779$ and *p-value* ($0.08895 \leq \alpha = 10\%$). Therefore, it is concluded that the PLN Inc. customer receivables data between provinces in Indonesia is indicated by spatial heterogeneity so that the spatial assumption on the data has been fulfilled.

Modeling Customer Receivables of PLN Inc. with GWR Approach

a. Selection of the Best Weight

In geographically weighted regression modeling, it is very important to have weights. In Tobler's law 1, said that basically everything is connected to each other, but if something is closer, it will have more influence than something far away (Miller, 2014).

Table 8. Selection of the Best Weight

Weighted Kernel	h Optimum	R-Square	SSE
<i>Fixed Gaussian</i>	12.96353	0.9694117	1,367,327
<i>Fixed Bi-Square</i>	15.32418	0.812868	1,460,164

Based on **Table 8**, the best weighting function is obtained from the highest R^2 value, namely the fixed gaussian. The R^2 value resulting from the fixed gaussian weighting is 0.9694117, this value indicates that the predictor variables are able to explain the diversity of PLN Inc. customer receivables in Indonesia by 96.94 percent and the rest is explained by other variables outside the model. Judging from the R^2 value, it can be concluded that the R^2 value in modeling with the GWR approach is greater than the R^2 value in multiple linear regression modeling which is only 44.34 percent. Thus, modeling PLN Inc. customer receivables using spatial regression with the GWR approach can explain better in the case of PLN Inc. customer receivables in Indonesia than the multiple linear regression method.

b. Parameter Estimation of GWR Model by Province

The Weighted Least Squares (WLS) method is used to estimate the parameters of the GWR model by assigning unequal weights to each location where the data is observed (Susanti, 2018). Based on the results of calculations using OSS-GWR4 software, that the intercept estimates and parameter estimates for each location are different, so that the results of modeling PLN Inc. customer receivables with a GWR spatial approach are summarized and presented in **Table 9** as follows:

Table 9. Customer Receivables Model of PLN Inc. by Province in Indonesia

No	Province	GWR Models
1	Aceh	$\hat{y}_1 = 82.36118 + 16.73124X_{1,1} - 1.01235X_{1,2} + 0.057463 X_{1,3} + 319.6003X_{1,4}$
2	North Sumatra	$\hat{y}_2 = 91.67000 + 16.90034X_{2,1} - 1.01278X_{2,2} + 0.051799 X_{2,3} + 320.7294X_{2,4}$
⋮	⋮	⋮
23	Banten	$\hat{y}_{23} = 142.96126 + 16.40136X_{23,1} - 0.9797X_{23,2} + 0.033294 X_{23,3} + 321.2325X_{23,4}$

Based on **Table 9** above, the model formed will be used to estimate PLN Inc. customer receivables for each province in Indonesia.

c. Partial Testing of Local Parameters of GWR Model

In identifying the effect of each parameter on PLN Inc. customer receivables in each location, partial testing is conducted. The results of this test will vary in each location because it depends on the resulting GWR model. The test statistic used is the T test through the formulation of the following hypothesis.

$$H_0: \beta_p(u_i, v_i) = 0, \quad p = 1, 2, \dots, k; \quad i = 1, 2, \dots, n$$

(The k predictor variable at the i location has no significant effect)

$$H_1: \beta_p(u_i, v_i) \neq 0$$

(The k predictor variable at the i location has a significant effect)

with $\alpha = 10\%$ it is decided to reject H_0 if the value of $|T_{i,p}| > t_{0.05}(r)$ with r is the degree of freedom $(n - 2tr(S) + tr(StS))$ or p-value $\leq \alpha$. Based on the calculation results using the OSS-GWR4 software, the value of the free degree r is 15.04673.

Based on the parameter estimation results, Papua and West Papua Provinces were selected as having the lowest PLN Inc. receivables in Indonesia.

Furthermore, the hypothesis for partial parameter testing in Papua and West Papua Provinces located in the 14th location is formulated as follows.

$$H_0: \beta_p(u_{14}, v_{14}) = 0, \quad p = 1, 2, \dots, k; \quad i = 1, 2, \dots, n$$

(The k predictor variable at the 14th location has no significant effect)

$$H_1: \beta_p(u_{14}, v_{14}) \neq 0$$

(The k predictor variable at the 14th location has significant effect)

The result of partial test for Papua and West Papua Province shown in **Table 11**.

Table 11. Partial Testing of Local Parameters of GWR Model for Papua and West Papua Provinces

Parameters	$ T_{14,p} $	$T_{(0.05, 15, 04673)}$	Conclusions
β_1	2.43770	2.13145	Reject H_0
β_2	2.58643		Reject H_0
β_3	4.46756		Reject H_0
β_4	2.32114		Reject H_0

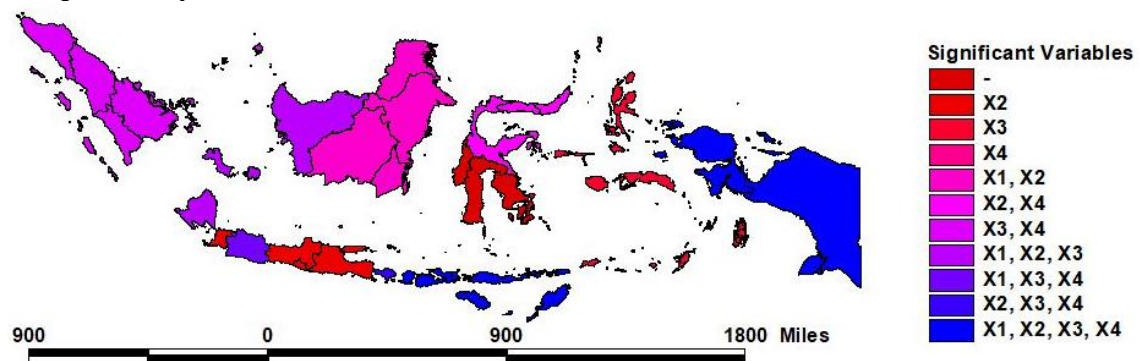
Based on **Table 11**, it is obtained that all parameters, namely $\beta_1, \beta_2, \beta_3$, and β_4 it is decided to reject H_0 . Thus, variables that have a significant effect on PLN Inc. Customer Receivables in Papua and West Papua Provinces are the average speed of billing, the number of employees, employee productivity, and the percentage of revenue from customers.

The result of partial testing of local parameters in each province can be arranged based on the similarity of significant predictor variables affecting the response variable. The grouping is summarized in **Table 12**.

Table 12. Provincial Grouping Based on Significant Variables

Group	Province	Significant Variables
1	South Sulawesi, Southeast Sulawesi, and West Sulawesi	-
2	Central Java and DI Yogyakarta, East Java, Banten	X_2
3	Maluku and North Maluku	X_3
4	South Sumatra, Jambi, and Bengkulu	X_4
5	South Kalimantan and Central Kalimantan, East Kalimantan and North Kalimantan	X_1, X_2
6	North Sulawesi, Central Sulawesi, and Gorontalo	X_2, X_4
7	Aceh, North Sumatra, West Sumatra, Riau, and Riau Island	X_3, X_4
8	Lampung, Bangka Belitung Island, DKI Jakarta, and West Kalimantan	X_1, X_2, X_3
9	West Java	X_1, X_3, X_4
10	Bali	X_2, X_3, X_4
11	Papua and West Papua, East Nusa Tenggara, West Nusa Tenggara	X_1, X_2, X_3, X_4

Based on **Table 12**, upon careful observation, it can be note that the variable employee Productivity (X_3) and revenue from customers (X_4) appear most frequently in the 11 existing groups. However, there are three provinces that are not influenced by the four predictor variables. This could potentially occur due to the influence of other variables not included in the model.

**Figure 2. Map of Provincial Distribution in Indonesia Based on Similarity of Significant Predictor Variables**

Based on **Figure 2**, it is known that provinces with similar significant predictor variables are located in relatively close regions. This is indicated in Aceh, North Sumatra, West Sumatra, Riau, and Riau Island provinces marked with purple, which have similarity in significant predictor variables, namely employee productivity (X_3), and revenue from customers (X_4).

d. GWR Model Fit Test

This test aims to compare the GWR model with global regression in explaining PLN Inc. customer receivables in Indonesia. The test statistic used is the F test through the following hypothesis formulation.

$$H_0: \beta_1(u_i, v_i) = \beta_2(u_i, v_i) = \dots = \beta_k(u_i, v_i) = \beta, i = 1, 2, \dots, n$$

(There is no significant difference between GWR model and global regression model)

$$H_1: \text{at least there is one } \beta_p(u_i, v_i) \neq \beta, p = 1, 2, \dots, k$$

(There is a significant difference between GWR model and global regression model)

At the significant level of $\alpha = 10\%$ the decision is made by rejecting H_0 if the value of the test statistic $F > F_{0.1; 2.9533; 15.0467} = 2.6952$ or p-value $\leq \alpha$. This test was conducted using OSS-GWR4 software, the summarized results are presented in **Table 13** below.

Table 13. GWR Model Fit Test

Source	SS	DF	MS	F
Global Residual	1,809,526	5,000		
GWR Improvement	442,199	2.9533	149,732	
GWR Residual	1,367,327	15.0467	90,872	3.0462

Based on **Table 13**, the value of F_{hit} is 3.0462 so it is decided to reject H_0 because the value of $F_{(3.0462)} > F_{(0.1; 2.9533; 15.0467)}$ which is $3.0462 > 2.6952$. Therefore, it can be concluded that there is a significant difference between the GWR model and the global regression model. Thus, it can

be stated that the GWR model is better at explaining PLN Inc. customer receivables in Indonesia than the global regression model.

e. Variability Test

Based on the parameter significance test in **Table 11**, it can be known that not all variables will have an effect at each location, giving rise to the suspicion that there are variables that are not local or do not have a location-dependent effect. Therefore, variability testing is conducted to determine whether there are variables that are not local. Parameters that are not local are referred to as global coefficients where the parameter estimate value is uniform across all observation locations. The following is the hypothesis formulation for the variability test.

$$H_0: \beta_p(u_1, v_1) = H_0: \beta_p(u_2, v_2) = \dots = H_0: \beta_p(u_n, v_n) = \beta_p, p \in \{1, 2, \dots, k\}$$

(There is no difference in the coefficient on variable X_k between one location and another)

$$H_1: \text{minimal ada satu } \beta_p(u_i, v_i) \neq \beta_p$$

(There is a difference in the coefficient on variable X_k between one location and another)

with $\alpha=10\%$, then the decision is made by rejecting H_0 if the value of the test statistic $F > F_{0.1; (0.1; \frac{c_1^2 b_1^2}{c_2^2 b_2^2})}$.

Table 14. Variability Test

Parameters	F_{score}	$F_{0.1; (0.1; \frac{c_1^2 b_1^2}{c_2^2 b_2^2})}$	Conclusions
$\hat{\beta}_1$	5.964501	2.128002	Reject H_0
$\hat{\beta}_2$	5.237947	2.087981	Reject H_0
$\hat{\beta}_3$	5.797401	2.178328	Reject H_0
$\hat{\beta}_4$	11.262503	3.048109	Reject H_0

Based on **Table 14**, it can be known that there are differences in parameter values between one location and another in all predictor variables. Therefore, it can be concluded that all predictor variables, namely average billing speed (X_1), number of employees (X_2), employee productivity (X_3), and revenue from customers (X_4) are local variables.

f. GWR Model Interpretation

Referring to **Table 11**, it is known that Papua and West Papua Provinces have the lowest PLN Inc. customer receivables in Indonesia. This can be caused by certain factors that affect the number of PLN Inc. customer receivables in Papua and West Papua Provinces. Through modeling with the GWR approach, the relationship between these factors and PLN Inc. customer receivables with the GWR model in Papua and West Papua Provinces can be identified as follows.

$$\hat{y}_{14} = 126.36411 - 1.74996X_{3,1} - 0.00493X_{3,2} - 0.0228X_{3,3} + 2.6146X_{3,4} \quad (2)$$

Based on the model in Equation (2), it can be interpreted that each one-day increase in the average speed of collection in Papua and West Papua Provinces will reduce the amount of PLN Inc. customer receivables by IDR 1,749,960,000,000. In addition, every increase of one employee in Papua and West Papua Provinces will reduce the amount of PLN Inc. customer receivables by IDR 4,930,000,000. All predictor variables in the model with negative coefficients have the same interpretation.

CONCLUSION

Based on the distribution map of significant predictor variables, provinces with adjacent areas tend to have the same significant variables. Therefore, it can be proven that PLN Inc. customer receivables is a spatial case where adjacent areas influence each other. Based on modeling with the GWR approach, PLN Inc. and the central and regional governments can solve customer receivables problems by focusing on improving variables that have a significant influence on subscription receivables in each province. Based on the model interpretation results from Papua and West Papua Provinces, recommendations can be formulated for PLN Inc. and the governments of Papua and West Papua Provinces. Firstly, to improve efficiency in the billing process, PLN Inc. is advised to clarify and enhance the billing targets that employees must achieve by increasing their work duration (days) in collecting customer receivables. Furthermore, based on

the 2022 BPS data, the lowest job vacancies are in Papua Province, with 255 job vacancies. Therefore, it is recommended for PLN Inc. to collaborate with the governments of Papua and West Papua Provinces to increase job vacancies, especially for PLN Inc. employees.

Thirdly, to enhance employee productivity, it is recommended for PLN Inc. to set the same number of customers as targets for each employee, so that they can provide optimal service in collecting receivables. The fewer customers handled, the more optimal the employee's performance in collecting customer receivables. Fourthly, it is known that until 2022, PLN Inc. has a prepaid and token system. However, compared to the prepaid system, the token method is considered superior because it reduces the risk of customer receivables. Therefore, it is recommended for PLN Inc. to replace the prepaid system with the token method for all customers. In this process, PLN Inc. can collaborate with the government to provide socialization to the public about the advantages of the token method. Thus, there will be a decrease in customer receivables and an increase in revenue from customers.

ACKNOWLEDGEMENTS

The authors would like to thank Mr Dr. Toha Saifudin, S.Si, M.Si. as a correspondence writer and Mrs Sa'idah Zahrotul Jannah, S.Si. M.Stat who has helped in improving this article. The authors would like to thank PLN INC.Inc. for providing the data for this study, as well as the members who collaborated effectively in completing this article.

REFERENCES

- Ajija, S. R., Sari, D. W., Setianto, R. H., and Primanti, M. R. (2011). *Cara Cerdas Menguasai Eviews*. Jakarta: Salemba Empat.
- Budiwanto, S., (2017). *Metode Statistika*. Malang: Universitas Negeri Malang.
- Clement, F., Orange, D., Williams, M., Mulley, C., and Epprecht, M. (2009). "Drivers of Afforestation in Northern Vietnam: Assessing Local Variations Using Geographically Weighted Regression," *International Journal of Applied Geography*, 29(4), 561-576.
- Desriwendi, Hoyyi, A., and Wuryandari T. (2015). "Pemodelan Geographically Weighted Logistic Regression (Gwlr) Dengan Fungsi Pembobot Fixed Gaussian Kernel Dan Adaptive Gaussian Kernel (Studi Kasus : Laju Pertumbuhan Penduduk Provinsi Jawa Tengah)," *JURNAL GAUSSIAN*, 4(2), 193-204.
- Fadli, M. R., Goejantoro, R., and Wasono. (2018). "Pemodelan Geographically Weighted Regression (GWR) Dengan Fungsi Pembobot Tricube Terhadap Angka Kematian Ibu (AKI) Di Kabupaten Kutai Kartanegara Tahun 2015," *Jurnal EKSPONENSIAL*, 9(1), 11-18.
- Ghozali, I. (2016). *Aplikasi Analisis Multivariate Dengan Program IBM SPSS 23 (VIII)*. Semarang: Badan Penerbit Universitas Diponegoro.
- Gujarati, D. N. (2003). *Basic Econometric*. Singapore : McGraw Hill.
- Matdoan, M. Y., Persulesy, E. R., and Lembang, F. K. (2016). "Analisis Preferensi Pelanggan Pt.Pln (Persero) Dalam Menentukan Atribut Rekening Listrik Prabayar Di Kota Ambon Dengan Menggunakan Metode Analisis Konjoin," *BAREKENG: Jurnal Ilmu Matematika dan Terapan*, 10(1), 37-46.
- Miller, H. J. (2004). "Tobler's First Law and Spatial Analysis," *Annals of the Association of American Geographers*, 94(2), 284-289.
- Susanti, Y. (2018). "Penerapan Model Geographically Weighted Regression(GWR) Pada Produksi Ubi Jalar," *Indonesian Journal of Applied Statistics*, 1(1), 52-69.
- Sya'diyah, Z. (2021). "Kestabilan Model Petri Net Dari Sistem Pembayaran Tagihan Listrik Pt. Pln (Persero) Rayon Ambon Timur," *BAREKENG: Jurnal Ilmu Matematika dan Terapan*, 15(4), 601-606.
- Talakua, M. W., Abrahams, H., and Lesnussa, Y. A. (2018). "Kajian Tentang Pendapat Pelanggan Pln Di Desa Passo Dan Desa Rumah Tiga Terhadap Listrik Prabayar Dengan

- Metode Analisis Variansi,” *BAREKENG: Jurnal Ilmu Matematika dan Terapan*, 12(1), 17-26.
- Usali, R., Nurwan, Oroh, F. A., and Payu, M. R. F. (2021). “Pemodelan Regresi Spasial Dependensi Pada Tingkat Partisipasi Angkatan Kerja Di Indonesia Tahun 2020,” *BAREKENG: Jurnal Ilmu Matematika dan Terapan*, 15(4), 687-696.
- Wattimena, F. N., Pentury, T., and Lesnussa, Y. A. (2012). “Aplikasi Petri Net Pada Sistem Pembayaran Tagihan Listrik Pt. Pln (Persero) Rayon Ambon Timur,” *BAREKENG: Jurnal Ilmu Matematika dan Terapan*, 6(1), 23-30.
- Tahir, M. A., & Irsan B, M. (2024). Rancang Bangun Panel Auto Transfer Switch (ATS) Pada Sistem Hybrid PLN – Panel Surya Berbasis Timer Switch. *G-Tech: Jurnal Teknologi Terapan*, 8(1), 554–564.