A Fixed Effect Panel Spatial Error Model in Identifying Factors of Poverty in West Java Province

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Abstract. In the last five years, poverty had been a major problem in West Java Province (WJP). Hence, it becomes a strategic development issue for the next five years. To contribute in eradicating the poverty, we aimed this study at identifying poverty factors and measuring their effects. There are two issues in modelling poverty in WJP. First, there was spatial dependency in poverty among regions. Second, due to data limitation, some important factors were not included in the empirical model. Both might lead to bias in regression parameter estimates. Accordingly, we applied a fixed effect panel spatial error model on the poverty rate in WJP. We found that health and economic welfare effected poverty.

1. Introduction
Indonesian Ministry of National Development Planning (Bappenas) [1] defines poverty as a condition in which a person or a group of people, men and women are unable to fulfill their basic rights to maintain and develop a dignified life. The basic rights of the community include the fulfillment of food, health, education, employment, housing, clean water, natural and environmental resources, security, and social and political rights. The first goal in Sustainable Development Goals (SDG’s) in Statistics Indonesia (BPS) [2] is to end poverty in all its forms everywhere. Indonesia as a developing country certainly has a big problem with poverty so the government makes poverty reduction a top priority for national development.

As a part of Indonesian Government, the Government of West Java Provinces (WJP) also set poverty as its strategic development issue in 2018-2023 [3]. Although poverty rates in WJP decreased during 2014-2018 and reached 7.45% which was lower than the nasional poverty rate of 9.82%, there were twelve regencies/cities whose poverty rates were higher than the hardcore level of 10% [5]. In assisting the Government of WJP to arrange effective and efficient programs for eradicating poverty, information on poverty’s factors is required. Hence, in this study, we intended to identify poverty factors and estimate their effects and a regression model was be used.

The following concerns were arised in modeling poverty to identify its factors and estimate their effects. First, the data used in this study is regional data (i.e. districts/cities’ data). Measurement results may spatially be dependent. Ignoring this dependency will lead to bias and inconsistency of parameter estimates [6]. Moreover, due to data availability, many important poverty factors (e.g. regional characteristics) were not included in the model. This also leads to estimates bias called omitted variable bias [7]. To overcome spatial dependency, we used spatial error model. And to handle omitted
variable bias used fixed effect panel model. Accordingly, to identify the factor and estimate their effects, we used a fixed effect panel spatial error model.

![Figure 1. Poverty Rate in West Java Province 2014-2018](image)

2. Method
2.1 Research Data
The selection of independent variables in this study refers to research conducted by Kartasasmita in Sa'diyah [8], the main determinant of poverty according to Haughton and Khandker [9], and several other studies. Based on research conducted by Amaluddin [10] in Maluku Province in 2008-2012, the increasing rate of life expectancy, average schooling, access to health facilities and clean water has an effect on poverty rates. Research conducted by Aida Meimela [11] shows that adjusted per capita consumption and underemployment rates negatively affected poverty in Indonesia in 2015-2017. Research conducted by Vijayakumar [12] shows that dependency ratios effects poverty rates positively while industry sector effects negatively. Based on the research that has been conducted, the independent variables used in this study includes the educational aspect as indicated by expected years of schooling, health as indicated by life expectancy, economics as indicated by adjusted per capita expenditure, and demographic aspect as indicated by dependency ratio.

| Variables                        | Unit       |
|----------------------------------|------------|
| Dependent Variable               | Poverty Rate (TK) | Percent |
| Independent Variables            |            |
| Expected Years of Schooling (AHLS)| Years     |
| Life Expectancy (AHH)            | Years      |
| Adjusted per Capita Expenditure (PK)| Million (IDR) |
| Dependency Ratio (DR)            | Percent    |

2.2 Multicollinearity
Multicollinearity is a state of some or all of the independent variables in modeling highly linearly related. The presence of multicollinearity in a model, according to Wooldridge [7], is indicated by its feasibility to use but many independent variables are not significant. To detect the presence of perfect multicollinearity can be seen from the matrix determinant (XX). If the determinant value is positive, then there is no perfect multicollinearity. In contrast, if the value is not positive, then there is perfect
multicollinearity on the independent variable. Perfect multicollinearity according to Greene [13] can result in incorrectly estimated regression coefficients.

However, if there is no perfect multicollinearity, the detection can be performed on the independent variables using Variance Inflation Factor (VIF). The formula used to calculate VIF values is as follows:

$$VIF_i = \frac{1}{\text{Tolerance}} = \frac{1}{1 - R_i^2}$$ (1)

$R_i^2$ is the coefficient of multiple determination from the estimation results of the $i^{th}$ independent regression model on other independent variables.

If VIF > 10, there has been multicollinearity on the independent variables in the regression model. The existence of multicollinearity can cause estimates to be sensitive to changes in data.

2.3 Spatial Weight Matrix

A Spatial weight matrix can be symbolized by $W$ which means $(N \times N)$ where $N$ is the number of units of the observation area. The spatial weight matrix that will be used is the queen contiguity method where this matrix is issued by regencies/cities in West Java Province intersecting on the sides and corners. Weighting is done by making a $C$ matrix which can be seen as follows:

$$C = \begin{bmatrix}
0 & c_{12} & \cdots & c_{1j} \\
c_{21} & 0 & \cdots & c_{2j} \\
\vdots & \vdots & \ddots & \vdots \\
c_{i1} & c_{i2} & \cdots & 0
\end{bmatrix}$$

If $i$ region that intersects with $j$ region, the value is $c_{ij} = 1$, and if it does not, it is $c_{ij} = 0$. The value of the $C$ matrix will be standardized so that it forms a spatial weight matrix ($W$) with the following equation:

$$w_i = \frac{c_{ij}}{\sum_{j=1}^{N} c_{ij}}$$ (2)

Geographically there are 26 regencies/cities in West Java Province so that the spatial weight matrix of queen contiguity formed will have a dimension of $26 \times 26$ with a main diagonal of zero value.

2.4 Spatial Dependence Test

Spatial dependence test on panel data according to Elhorst [14] can use the Lagrange Multiplier (LM) test for spatial error models. The hypothesis for the Lagrange Multiplier (LM) test is as follows:

$H_0: \lambda = 0$ (there is no spatial autocorrelation in the error)

$H_1: \lambda \neq 0$ (there is a spatial autocorrelation in the error)

Statistical Test:

$$LM_{\lambda} = \frac{\bar{e}'(I_{N} \otimes W)\bar{e}}{\hat{\sigma}^2}$$ (3)

With:

$$\bar{e} = \left( y - X\hat{\beta} \right), \hat{\sigma}^2 = \frac{\bar{e}'e}{NT}, \text{ and } T_W = \text{tr}(WW + WW)$$

Test Criteria:

Reject $H_0$ if the LM test value is greater than the value of the chi-square distribution with one degree of freedom ($\chi^2_{(1)}$) or reject $H_0$ if p-value $\leq \alpha$, accept in other cases.

2.5 Fixed Effect Panel Spatial Error Model
According to Elhorst [14], the fixed effect panel spatial error model is as follows:

\[
y_{it} = \sum_{k=1}^{K} \sum_{j=1}^{N} x_{jk} \beta_k + \mu_i + u
\]  
(4)

\[
u_{it} = \lambda \sum_{j=1}^{N} w_{ij} u_j + \epsilon_{it}
\]  
(5)

The matrix form is as follows:

\[
y = X\beta + (I_T \otimes I_N)\mu + u
\]  
(6)

\[
u = \lambda W_{NT} u + \epsilon
\]  
(7)

With:

- \(y\) : vector dependent variable sized \(NT \times 1\)
- \(X\) : independent variables matrix sized \(NT \times k\)
- \(\lambda\) : coefficient of spatial parameters error
- \(\beta\) : independent parameter vector sized \(k \times 1\)
- \(\epsilon\) : measuring error vector \(NT \times 1\) and \(\epsilon \sim N(0, \sigma_{\epsilon}^2)\)
- \(u\) : measuring error vector \(NT \times 1\)
- \(\mu\) : matrix effects sized individuals \(N \times 1\)
- \(W_{NT}\) : spatial weight matrix sized \(NT \times NT\)
- \(I_T\) : vector sized \(T \times 1\) that each of whose entries contains the value 1
- \(I_N\) : the identity matrix sized \(N \times N\)

Estimating parameters in this study uses the maximum likelihood method. This method is used to get statistics that maximize the log likelihood function. The log likelihood function of getting the estimated parameters in this study is as follows:

\[
\ln L(\mu, \beta, \sigma^2, \lambda; y_{11}, ..., y_{NT}) = -\frac{NT}{2} \ln \left(2\pi \sigma^2\right) - T \ln |I_N - \lambda W_N| - \frac{1}{2\sigma^2} ... \\
((I_T \otimes (I_N - \lambda W_N))(y - X\beta - (I_T \otimes I_N)\mu))'((I_T \otimes (I_N - \lambda W_N))(y - X\beta - (I_T \otimes I_N)\mu))
\]  
(8)

Estimated parameters obtained by maximizing the log-likelihood function simultaneously against \(\frac{\partial \ln L}{\partial \mu} = 0, \frac{\partial \ln L}{\partial \sigma^2} = 0, \frac{\partial \ln L}{\partial \beta} = 0, \) and \(\frac{\partial \ln L}{\partial \lambda} = 0.\)

\[
\hat{\beta} = \left[\left(X' - (I_T \otimes \lambda W_N)X'\right)^{-1}\left(X' - (I_T \otimes \lambda W_N)X'\right)\right](y' - (I_T \otimes \lambda W_N)y')
\]  
(9)

\[
\hat{\sigma}^2 = \frac{\left((I_T \otimes (I_N - \lambda W_N))(y^* - X^*\hat{\beta})\right)'\left((I_T \otimes (I_N - \lambda W_N))(y^* - X^*\hat{\beta})\right)}{NT}
\]  
(10)

Estimated parameters are obtained by maximizing the log likelihood function simultaneously on Parameter estimators \(\lambda\) which are obtained iteratively until they produce convergent values. To make inferential, asymptotic variance matrix by defining \(\hat{W} = W(I_N - \lambda W)^{-1}\) as follows:
2.6 Assumption Testing

Assumption testing is performed to find the best regression model that provides the accuracy of the estimation results. Testing assumptions in spatial regression includes homoscedasticity tests, non-autocorrelation tests, and normality tests.

2.6.1 Homoscedasticity

The first assumption test is the homoscedasticity assumption. If the assumption is violated, it will cause heteroscedasticity. Heteroscedasticity is a condition where the error variance is not constant. This condition can result in estimating inefficient parameters so that they do not have a minimum variation. Testing that can be performed to detect heteroscedasticity involves the Breuch-Pagan Lagrange Multiplier Test. The testing hypothesis is as follows:

\[ H_0 : \sigma^2 = \text{homoscedasticity error variance} \]

\[ H_1 : \sigma^2 \neq \text{homoscedasticity error variance} \]

with \( i = 1,2,\ldots,26 \) \( t = 1,2,\ldots,6 \) and \( \alpha = 0.05 \)

Statistical Test:

\[ BP = \frac{1}{2} g' X (X' X)^{-1} X' g \] (12)

With \( g = \frac{\hat{e}_i^2}{\left( \hat{e}_i^2 / NT \right)} - 1 \) and \( e = \left( I_T \otimes (I_N - \lambda \hat{W}_N) \right) y - X \hat{\beta} - \left( I_T \otimes I_N \right) \hat{u} \)

With:

- \( X \): independent variables matrix
- \( g \): observation vector \( g_i \)
- \( e_i \): residuals observation \( i \) dan time \( t \)
- \( e \): vector residuals observation
- \( N \): the number of observation; \( i = 1,2,\ldots,N \)
- \( T \): the number of time; \( t = 1,2,\ldots,T \)

Test Criteria:

Reject \( H_0 \) if \( BP > \chi^2_k \) or \( p\text{-value} \leq \alpha \), accept in other cases.

2.6.2 Non-Autocorrelation Spatio Temporal

Spatio-temporal non-autocorrelation testing using the Moran ST Index value according to Jaya et al [15], the hypotheses and test statistics used are:

\( H_0 : \rho = 0 \) (there is no spatio-temporal autocorrelation in the observation error)

\( H_1 : \rho > 0 \) (there is a spatio-temporal autocorrelation in the observation error)

with \( \alpha = 0.05 \)

Statistical Test:
The hypothesis are as follows:

1. \( H_0 : \lambda = 0 \) (there is no a spatial dependency error)
2. \( H_1 : \lambda < 0 \) (there is a spatial dependency error)
3. \( H_{11} : \beta_1 < 0 \) (there is a negative effect of the expected years of schooling on poverty rates)
4. \( H_{12} : \beta_2 < 0 \) (there is a negative influence of life expectancy on poverty rates)
5. \( H_{13} : \beta_3 < 0 \) (there is a negative influence of per capita expenditure adjusted for poverty rates)
6. \( H_4 : \beta_4 = 0 \) (there is no influence of the ratio of dependence on poverty rates)
7. \( H_{14} : \beta_4 < 0 \) (there is a positive effect of dependence ratio on poverty rates)

with \( \alpha = 0.05 \)
Statistical Test:
By defining \( \hat{\theta} = (\hat{\lambda}, \hat{\beta}_1, \hat{\beta}_2, \hat{\beta}_3, \hat{\beta}_4) \), wald test statistics as follows:

\[
W_{\hat{\theta}} = \frac{\hat{\theta}}{se(\hat{\theta})}
\]

Test Criteria:
Reject \( H_0 \) if p-value \( \leq \alpha \), accept in other cases.

3. Results and Discussion
3.1 Model Specifications
The empirical model is the initial stage carried out to model the relationship between the independent variables and the dependent variables written in the form of a fixed effect panel spatial error model. The poverty rate in West Java is influenced by several factors, including the expected years of schooling (AHLS), life expectancy (AHH), adjusted per capita expenditure (PK), and dependency ratio (DR). The empirical model of the fixed effect panel spatial error method in this research is as follows:

\[
TK_{it} = \left( \beta_0 + \mu_t \right) + \beta_1 \text{AHLS}_{it} + \beta_2 \text{AHH}_{it} + \beta_3 \text{PK}_{it} + \beta_4 \text{DR}_{it} + u_{it}
\]

With \( u_{it} = \hat{\lambda} \sum_{j=1}^{N} W_{ij} u_{jt} + \varepsilon_{it} \), \( i = 1, 2, \ldots, 26 \) and \( t = 1, 2, \ldots, 6 \)

3.2 Multicollinearity
The results of the calculation of perfect multicollinearity show the determinant value \((XX^T) = 4.47 \times 10^{13}\). The results show a positive value so it can be concluded that there is no perfect multicollinearity. The next step is to see whether there is multicollinearity among independent variables using Variance Inflation Factor (VIF). The results of the calculation of VIF values are as follows:

| Independent Variables                  | VIF Value |
|----------------------------------------|-----------|
| Expected Years of Schooling            | 1.67      |
| Life Expectancy                        | 2.37      |
| Adjusted per Capita Expenditure        | 3         |
| Dependency Ratio                       | 1.13      |

Based on Table 2, it can be concluded that there is no multicollinearity among the independent variables used because there are no independent variables that have a VIF value greater than 10.

3.3 Spatial Weight Matrix
The standardized spatial weight matrix results in a spatial weight matrix \( W \) which has 26 x 26 dimensions is as follows:

\[
W = \begin{bmatrix}
0 & 0.125 & 0.125 & \cdots & 0 \\
0.333 & 0 & 0.333 & \cdots & 0 \\
0.166 & 0.166 & 0 & \cdots & 0 \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
0 & 0 & 0 & \cdots & 0
\end{bmatrix}
\]
3.4 Spatial Dependence Test
Spatial dependence test results are obtained using the Lagrange Multiplier test as follows:

Table 3. Spatial Dependence Testing

|            | LM    | p-value |
|------------|-------|---------|
|            | 30.227 | 0.0000  |

Based on Table 3, the LM value is greater than the value $\chi^2_{(1)} = 3.841459$ or $p$-value $\leq \alpha = 0.05$, the $H_0$ is rejected so it can be concluded that there are dependencies/autocorrelation of spatial error among regencies/cities in West Java Province.

3.5 Estimated Parameters
Estimated fixed effect panel spatial error model parameters use the maximum likelihood method with the help of R software with the following results:

Table 4. Estimated Regression Coefficient

| Parameters                        | Estimate | Standard Error | Wald    | p-value |
|-----------------------------------|----------|----------------|---------|---------|
| Spatial Coefficient Error ($\lambda$) | 0.5532   | 0.0777         | 7.1228  | 0.0000  |
| Slope Variable AHLS ($\beta_1$)   | -0.2177  | 0.1469         | 1.4822  | 0.0691  |
| Slope Variable AHH ($\beta_2$)    | -0.5998  | 0.2363         | 2.5380  | 0.0056  |
| Slope Variable PK ($\beta_3$)     | -0.4784  | 0.1352         | 3.5379  | 0.0002  |
| Slope Variable DR ($\beta_4$)     | 0.0114   | 0.0077         | 1.4703  | 0.0707  |
| Intercept ($\beta_0$)             | 59.4150  | 14.1966        | 4.1852  | 0.0000  |
| Intercept Bogor                   | -1.5099  | 14.0229        | -0.1077 | 0.5429  |
| Intercept Sukabumi                | -3.0004  | 14.0366        | -0.2138 | 0.5341  |
| Intercept Cianjur                 | -0.6882  | 13.9672        | -0.0493 | 0.5196  |
| Intercept Bandung                 | -1.2431  | 14.5349        | -0.0855 | 0.5341  |
| Intercept Garut                   | 0.2415   | 14.2577        | 0.0169  | 0.4932  |
| Intercept Tasikmalaya             | -1.5016  | 13.7853        | -0.1089 | 0.5434  |
| Intercept Ciamis                  | -1.9584  | 14.1718        | -0.1382 | 0.5550  |
| Intercept Kuningan                | 3.7868   | 14.5306        | 0.2606  | 0.3972  |
| Intercept Cirebon                 | 3.7977   | 14.2005        | 0.2674  | 0.3946  |
| Intercept Majalengka              | 1.4388   | 13.7919        | 0.1043  | 0.4585  |
| Intercept Sumedang                | 1.2684   | 14.3162        | 0.0886  | 0.4647  |
| Intercept Indramayu               | 3.5755   | 14.0967        | 0.2536  | 0.3999  |
| Intercept Subang                  | 1.6567   | 14.1833        | 0.1168  | 0.4535  |
| Intercept Purwakarta              | -1.0657  | 13.8378        | -0.0770 | 0.5307  |
| Intercept Karawang                | 0.8539   | 14.1501        | 0.0603  | 0.4759  |
| Intercept Bekasi                  | -3.2879  | 14.4875        | -0.2269 | 0.5898  |
| Intercept Bandung Barat           | 1.2274   | 14.4165        | 0.0851  | 0.4661  |
| Intercept Kota Bogor              | -0.8522  | 14.4012        | -0.0592 | 0.5236  |
| Intercept Kota Sukabumi           | -0.8573  | 14.2595        | -0.0601 | 0.5240  |
| Intercept Kota Bandung            | -0.6633  | 14.1721        | -0.0468 | 0.5187  |
| Intercept Kota Cirebon            | 1.0923   | 14.1628        | 0.0771  | 0.4693  |
| Intercept Kota Bekasi             | 0.1262   | 14.3696        | 0.0088  | 0.4965  |
| Intercept Kota Depok              | -3.1625  | 14.3097        | -0.2210 | 0.5875  |
| Intercept Kota Cimahi             | -1.6528  | 14.5178        | -0.1138 | 0.5453  |
| Intercept Kota Tasikmalaya        | 5.5109   | 14.2208        | 0.3875  | 0.3492  |
| Intercept Kota Banjar             | -3.1328  | 13.9477        | -0.2246 | 0.5889  |
Based on the results of the estimated parameters in Table 4, the estimated parameters for spatial error show positive values, meaning that the error of an area has a dependency that is in the direction of the error in the adjacent region. Then for the parameter estimate $\beta_1$, $\beta_2$, and $\beta_3$ shows a negative value, meaning that the influence exerted by the variable length of school expectations, life expectancy, and expenditure per capita has an inversely proportional relationship with the poverty rates. Whereas the estimated parameter $\beta_4$ shows a positive value, meaning that the influence given by the dependency ratio variable has a direct relationship with the poverty rates.

3.6 Assumption Testing
3.6.1 Homoskedastisitas
Test criteria for the Breusch-Pagan test are to reject $H_0$ if the value of $BP \geq \chi^2_{(k)}$, and to accept other cases. Based on the calculation results, it is obtained $BP = 4.774 < \chi^2_{(4)} = 9.488$ or p-value = 0.3113 is greater than $\alpha = 0.05$ then $H_0$ is accepted. In conclusion, the error variance is homoscedasticity so that the assumption of homoscedasticity is fulfilled.

3.6.2 Non-Autokorelasi Spasio Temporal
Spatio-temporal non-autocorrelation testing can be done using the Moran ST Index value. Based on the calculation results, the MoranST value of $-0.04289$ with p-value = 0.7176 $> \alpha = 0.05$, so $H_0$ is accepted. It can be concluded that there is no spatio-temporal autocorrelation in the model error.

3.6.3 Normality
Testing the normality assumption in this study uses the Jarque-Bera test statistics. The test criteria for the Jarque-Bera test is to reject $H_0$ if the value $JB \geq \chi^2_{(2)}$ or p-value $\leq \alpha$, accept in other cases. Based on the results of calculations, the value obtained is $JB = 4.949 < \chi^2_{(4)} = 9.488$ or p-value = 0.0842 $> \alpha = 0.05$ then $H_0$ is accepted. To conclude, errors are normally distributed.

3.7 Interpretation
The spatial error panel fixed effect model is a model that accommodates spatial errors and fixed effects where the intercept for each unit of region is different. Based on the test results of the significance of the parameters in Table 4, shows that the spatial error coefficient has a p-value $\leq 0.05$, that meaning that there are spatial error dependencies among regions whose distance is close one another. Then the slope variable of expected years of schooling has a p-value $\geq 0.05$ which means the expected years of schooling variable does not significantly affect poverty rates. The slope of the life expectancy variable and the adjusted per capita expenditure variable has a p-value $\leq 0.05$ which means that both of these variables significantly influence poverty rates. Life expectancy variables and adjusted per capita expenditure variables are negatively related to poverty rates in West Java.

Based on the analysis results in Table 4, the Fixed Effect Panel Spatial Error model is as follows:

$$TK = (59.415 + \mu_t) - 0.5998AHH - 0.4784PK + u_t$$

$$u_t = 0.5532 \sum_{j=1}^{N} w_{ij} u_j + \varepsilon_t$$

The equation above can be interpreted that the estimated value $\beta_2$ shows that if the life expectancy variable increases one year, the poverty rate will decrease by 0.59998 percent, assuming the other variables are constant. The estimated value $\beta_3$ shows that if the adjusted per capita expenditure variable increases by one million rupiah, the poverty rates will decrease by 0.94784 percent, assuming other variables are constant.
4. Conclusion
Based on the results of the analysis using the Fixed Effect Panel Spatial Error Model method, it can be concluded that the level of health as indicated by the variable life expectancy and the level of the economy as indicated by adjusted per capita expenditure variables has a significant negative effect on poverty rates in West Java. These variables are factors that cause high poverty rates in West Java Province. Therefore, the government as a policy maker in dealing with poverty issue can consider these factors in making policies to deal with the issue highlighted that economic development must be carried out fairly and equally.

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